



Lawrence Livermore National Laboratory
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**Rare Plant Restoration and Monitoring at
Lawrence Livermore National Laboratory
Site 300
Project Progress Report
Fiscal Year 2002
October 2001–September 2002**

Authors

**Tina Carlsen
Lisa Paterson
Erin Espeland**

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Environmental Protection Department
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Executive Summary

Three extremely rare native plant species occur at Site 300: (1) *Amsinckia grandiflora*, a federally-listed endangered borage, (2) *Blepharizonia plumosa*, a late-flowering tarplant that is extremely rare throughout its range, (3) *Eschscholzia rhombipetala*, the diamond-petaled poppy which was not seen from 1950 to 1993 and presumed extinct. A fourth rare species, *Erodium macrophyllum*, the round-leaved filaree, is endangered throughout its range, but is not state- or federally-listed at this time. Four more uncommon native plant species occur at Site 300. These species are on the California Native Plant Society watch list indicating a degree of rarity, but each has a wide enough distribution so as not to be threatened at this time: (1) *Androsace elongata* subsp. *acuta*, California rock jasmine, (2) *Delphinium gypsophilum* ssp. *gypsophilum*, the gypsum-loving larkspur, (3) *Fritillaria agrestis*, stinkbells, and (4) *Hesperis matronalis*, hogwallow starfish. This report summarizes the detailed work performed on the three extremely rare species occurring at Site 300 for the 2002 fiscal year and the characteristics and habitat preferences for the other four newly-discovered rare and uncommon species: *A. elongata* subsp. *acuta*, *F. agrestis*, *H. caulescens*, and *E. macrophyllum*. Due to manpower limitations and the relative lack of statewide rarity for *Delphinium gypsophilum* subsp. *gypsophilum*, no population mapping was done for this species in FY2002 as was performed the previous year.

Amsinckia grandiflora, *Blepharizonia plumosa* and *Eschscholzia rhombipetala* all have varying levels of statewide rarity and abundance at Site 300, hence research and management of each species is different. *Amsinckia grandiflora* currently occurs in two populations at Site 300: one native population (an additional native population has been extirpated for three years) and one experimental population. The goal of research and management of *A. grandiflora* populations is to control the cover of exotic annual grasses while developing techniques to restore native perennial grasslands and to preserve *A. grandiflora* numbers. *Blepharizonia plumosa* occurs in large numbers throughout Site 300, and thus occurs in areas of active Site 300 operations. However, its close relative, *B. lutea* is not common at Site 300. Efforts are focused on determining the effects of fire on the distribution of both species and identifying possible metapopulation dynamics controlling the Site 300 *B. plumosa* populations. *Eschscholzia rhombipetala* is found in two small populations. One (site 1) is in the southwestern corner of Site 300 on a small landslide. The other (site 2) is in a steeply sloping grassland north of Building 854. Because both populations are extremely small and one occurs at a geologically unstable location, low-impact population demographic and community association data are all that are being collected at this time.

Amsinckia grandiflora Work

Activity Summary

Sixty *A. grandiflora* seeds were added to each plot in the Fire Frequency (FF) area to enhance the seed bank in that area. The fire frequency experiment in the FF area was continued, with only high frequency plots burned this year. Both the experimental population and the native population were censused in the spring. Biomass was collected from the flashing (FL) plots and

from the ongoing lupine monitoring continued. Seed predation in the experimental population was monitored both before and after the burn.

Results Summary

- Population numbers were low in the native population (19 plants, up from 14 in 2001) and decreased in the experimental FL subpopulation (10 plants, compared to 59 in 2001).
- The experimental FF subpopulation contained 57 plants in 2002, compared to 257 plants in 2001. In both years, most plants were too small to have set any seed.
- Biomass in the FL plots is beginning to increase after a drop in 2001. Biomass in the FL plots is now nearly twice (20 g/0.1m²) the levels found the previous year (11 g/0.1m²).
- Seed predation was quite low in the round conducted before the burn, with percent seeds lost at less than 50%. This is similar to levels observed the previous year. Burned, open plots experienced total predation (100%) and nearby unburned plots lost about half their seeds (56%). Plots in the FL area post-burn had lower predation levels of 20%.
- While nearly half of the *Lupinus albifrons* plants in the native population are dead or dying (19 out of 42), the population of *L. albifrons* is not diminishing: 14 of the 42 plants are newly established in 2002.

Blepharizonia plumosa Work

Activity Summary

All populations at Site 300 were visually mapped when plants were flowering in fall 2001. Selected populations of *B. plumosa* and its more common relative *B. laxa* were sampled prior to spring burns, after spring burns and at fall flowering. Survivorship, height, nearest neighbor, and microtopological data were collected.

Results Summary

- Very few plants survived the burn.
- Species diversity is high at Building 850 (H'=1.79) and Elk Ravine (1.87). Diversity is lower at the Middle Canyon *B. laxa* population (1.67) and at the Building 812 *B. plumosa* population (1.64).
- Small populations of *B. plumosa* were found throughout the mapped area of Site 300 in fall of 2001. Populations of *B. plumosa* in 2000 were larger and generally occurred at edges of areas burned in the previous and current year.

Eschscholzia rhombipetala Work

Activity Summary

Both *Eschscholzia rhombipetala* populations (site 1 and site 2) were censused at flowering. Plant height, and number of flowers were recorded. Location (slump, scarp or grassland) was

recorded for the site 1 population. Regressions to predict reproductive output from plant height data were developed. Community composition data were collected from plots located within the populations and in the areas surrounding them. Soil sampling was conducted to characterize the soils upon which this plant may be found.

Results Summary

- The *E. rhombipetala* population at site 1 this year was the largest to date, with 285 plants. This is an increase over 189 plants in 2001 and 273 plants in 1999. The site 2 population contained 76 plants in 2002.
- In 2002, most of the plants were found in the scarp at site 1 but the largest plants were in the slump. Slump plants at site 1 were as large as the plants found at site 2.
- *Eschscholzia rhombipetala* was positively associated with exotic forb cover and the presence of bare ground in the plots. Plants were less likely to be found in areas with high exotic grass cover and high amounts of thatch.
- Soils at site 1 and site 2 were clay and clay loam.

New Discoveries of FY2002

A botanical inventory of Site 300 was completed in 2002 (Preston, 2002). Field surveys were conducted in late April and May of 1997, March and April in 2002, and September of 2002. These field surveys consisted of walking meandering transects that traversed the entire site. All species encountered during these transects were recorded and the location of special status species were mapped. In addition, at each special status species occurrence, the number of individuals observed, a habitat description, and associated species were recorded. As a result of the 2002 field surveys, four special status plant species were discovered. These species were either not previously known to occur at Site 300, previously known from Site 300 but not considered rare until recently, or previously misidentified. Three of the rare species were identified in 2002: California rock jasmine (*Androsace elongata* subsp. *acuta* [Greene] Robbins), stinkbells (*Fritillaria agrestis* Greene), and hogwallow starfish (*Hesperovax caulescens* [Benth.] Gray), are included on the California Native Plant Society's List 4 (CNPS, 2001). List 4 includes species of limited distribution that are not considered rare from a statewide perspective, but are uncommon enough that their status should be monitored regularly. The third species, round leaved filaree, *Erodium macrophyllum* H. & A., is a California Native Plant Society List 2 species (CNPS, 2001). List 2 includes plants that are rare, threatened, or endangered in California, but more common elsewhere.

Androsace elongata subsp. *acuta* was found in 37 locations at Site 300 during the 2002 botanical inventory (Preston, 2002). This species was previously observed at Site 300 during the 1986 botanical surveys (Biosystems, 1986), although at that time its distribution was not well known, and it was not considered rare (Preston, 2002). At Site 300, *A. elongata* subsp. *acuta* is found on moss and lichen covered banks and rock outcrops on north facing slopes at elevations between 300 and 375 meters.

Prior to 2002, when one population of 200 plants was observed at Site 300, *Erodium macrophyllum* was previously not known to occur at Site 300 (Preston, 2002). This population occurs in the fire trails and on adjacent berms that are annually graded behind Building 851 in an area vegetated by annual grassland communities.

During the 2002 Site 300 botanical surveys, *Fritillaria agrestis* was found in five locations in the northwest corner of Site 300 (Preston, 2002). One of these five locations contained several hundred plants while the remaining four areas had less than 100 plants. *Fritillaria agrestis* was also found during 1986 rare plant surveys conducted at Site 300 (BioSystems, 1986), but it was misidentified as *Fritillaria biflora* (Preston, 2002).

Hesperovax caulescens was observed in one location at Site 300 during the 2002 botanical surveys in native grasslands (Preston, 2002). This population is located on an east-facing slope in an area with friable clay soils. *Hesperovax caulescens* was also previously identified at Site 300 during the rare plant surveys conducted in 1986 (Biosystems, 1986) although this species was not known to be rare at that time.

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Section A
Amsinckia grandiflora
Monitoring and Research

Section A

Amsinckia grandiflora Monitoring and Research

A-1. Introduction

The large-flowered fiddleneck, *Amsinckia grandiflora* (Gray) Kleeb. ex Greene (Boraginaceae), is a rare annual forb native to the California winter annual grasslands. *A. grandiflora* germinates with the onset of fall or early winter rain, grows vegetatively throughout the winter, flowers in the early spring, sets seeds and dies prior to the summer drought, a pattern observed in most of the herbaceous species in the California winter annual grasslands (Heady, 1990). Of the fifteen species in the genus recognized by Ray and Chisaki (1957a and 1957b), *A. grandiflora* is one of four heterostylous species with highly restricted distributions that are probably ancestors of the weedy, widespread, and homostylous congeners (Ray and Chisaki, 1957a and 1957b; Schoen et al., 1997). As a heterostylous species, *A. grandiflora* produces pin and thrum flower forms (also known as morphs). Each individual plant has only one type of flower. Pin flowers are characterized by having an exserted stigma and anthers within the corolla tube. Thrum flowers have the opposing morphology, with exserted anthers and the stigma within the corolla tube (Figure A1). Characteristic of the genus, each flower type has four ovaries at the base of the style, each of which matures into a seed, known as a nutlet. Thus, each flower can produce a maximum of four nutlets.

A. grandiflora has been recently known from only three natural populations containing individuals numbering from fewer than 30 to several thousand. All natural populations occur on steep, well-drained north facing slopes in the Altamont Hills of the Diablo range, about 30 km southeast of San Francisco, California. The populations occur at low elevations (approx. 300 m) and border on blue oak woodland and coastal sage scrub communities. Two of the natural populations occur on LLNL Site 300, a high-explosive testing facility operated by the University of California for the United States Department of Energy. The two natural populations at Site 300 are known as the Drop Tower population and the Draney Canyon population. Located in the north/southwest trending Drop Tower canyon, the Drop Tower population is the larger of the two populations at Site 300 and was the only known population of *A. grandiflora* up through 1987. In 1987, the Draney Canyon population was discovered in a north/southwest trending canyon to the west of the Drop Tower canyon. This population is now believed to have been extirpated. In 1993, a large *A. grandiflora* population, known as the Carnegie Canyon population, was discovered on private rangelands near the southeast border of Site 300. Attempts at establishing two experimental populations have also occurred near Site 300. Located adjacent to the southeast border of Site 300 is an ecological reserved owned by the California Department of Fish and Game (CDFG). An attempt was made to establish an experimental population of *A. grandiflora* at this site (known in Pavlik, 1994 as the Corral Hollow population), but no reproductive plants have been observed at this site in recent years, suggesting the establishment was not successful. Also near the southeast border of Site 300 is the Connolly Ranch, a privately owned ranch. An experimental population at this site was attempted, but failed, possibly as a result of extremely high rodent activity (Pavlik,

1994). Figure A2 shows the approximate locations of the *A. grandiflora* populations at or near Site 300.

Amsinckia grandiflora was federally listed as endangered in 1985. On May 8, 1985, one hundred and sixty acres of LLNL surrounding the native Drop Tower *A. grandiflora* population was designated critical habitat by the U.S. Fish and Wildlife Service (USFWS). In 1997, the USFWS published the final recovery plan for the species (USFWS, 1997). On April 28, 2000, the Secretary of the U.S. Department of Energy established the *Amsinckia grandiflora* reserve on the 160 acres of critical habitat and signed a memorandum of agreement with the USFWS describing technical services, management and access to the reserve (USDOE, 2000).

Restoration efforts began in 1988 by researchers from Mills College. These efforts focused on determining the factors necessary for the successful establishment of additional populations of *A. grandiflora* (Pavlik, 1988a and 1988b), and have resulted in the establishment of at least one apparently successful experimental population at Lougher Ridge (Pavlik, 1994). Between 1993 and 1995 using funds obtained through a grant from LLNL's Laboratory Directed Research and Development Program, LLNL researchers teamed with researchers from Mills College to further investigate the causes of *A. grandiflora* rarity and to establish an additional population at Site 300. The experimental population was established near the Drop Tower native population on a north-facing slope on the eastern fork of the Drop Tower canyon where it bifurcates around the Drop Tower facility parking lot (Figure A3). This population is known as the Drop Tower experimental population.

Research on the Drop Tower experimental population, the Lougher Ridge experimental population, and data from management of the Drop Tower natural population indicated that competition from exotic annual grasses was contributing to the decline of *A. grandiflora*, and that long term management to reduce exotic annual grass cover and restore and maintain the native perennial bunch grass community was necessary to ensure the persistence of this species (Pavlik et al., 1993; Pavlik, 1994; Carlsen et al., 2000). Long-term financial support is being provided through LLNL Site 300 management. Additional funding has been provided by the U. S. Fish and Wildlife Service and the U. S. Bureau of Reclamation.

The goal of the ongoing management of the Site 300 *A. grandiflora* populations is to control the cover of exotic annual grasses while developing techniques to restore native perennial grasslands. The use of controlled burning is being investigated as a tool for developing and maintaining perennial grasslands. Finally, the impact of seed predation is being investigated to determine its impact on the population dynamics of *A. grandiflora*. This report details progress made during the 2002 federal fiscal year (October 2001 through September 2002).

A-2. Methods and Materials

A-2.1. Burn of the Fire Frequency Subpopulation

The FF subpopulation consists of twenty plots were created in the FF subpopulation: five control plots that will not be burned after the initial burn (1998), five low frequency plots that will be burned once every five years, five medium frequency plots that will be burned once every three years, and five high frequency plots that will be burned each year. Figure A4 shows the layout of these plots. The population was established by initially burning the entire area of the FF

subpopulation in 1998. Perennial bunch grasses (*Poa secunda*) were planted in the center portion of each FF plot in 1999 (Carlsen et al., 2001) and allowed to establish in 1999–2000, as were *A. grandiflora* transplanted into the plots. Perennial bunch grasses were planted at the same intermediate density in each plot. In 2001, plot burn treatments were selected using a randomized block design. Because of the nature of the burns, it was important that no two plots of the same treatment be adjacent to each other. This extra stipulation for plot selection prevented areas from acting ecologically as larger 2.5 m \times 1 m blocks, rather than the intended 1 m \times 1 m areas. Burn treatments began in the summer of 2001. All FF plots except the control plots were burned on 18 Jul 01, and on 20 June 02, the high frequency FF plots were burned.

A-2-2. Fire Frequency Subpopulation Enhancement

The *A. grandiflora* seed bank in the FF plots was enhanced by planting 60 seeds per plot on 9 June 02 before the annual burn. These seeds were planted in the center square meter of each FF plot. Seeds were evenly spaced in 11 rows of five or six seeds. Of the twenty FF plots, only the five high frequency plots were burned. The success of these seeds will be measured in the 2003 spring census and reported in the 2003 fiscal year annual report.

A-2-3. Spring Census

The census of the FF and FL subpopulations took place on 27 Mar 02. The flower morph, plant height, and inflorescence number were recorded for each *A. grandiflora*, and these plants were flagged. The identity of the nearest species (nearest neighbor) was also recorded. Specific plant cover estimates were taken from a 60 cm \times 60 cm area in the center of each FF plot. Twelve random 60 cm \times 60 cm locations within the FL population were selected for cover estimates as well. Cover estimates in this subpopulation were taken from areas within the plots and also next to the plots.

The native Drop Tower population census was also conducted on 27 Mar 02. Flower morph, plant height and branch number were recorded for each plant. Branch number is defined as the number of major branches off the main stem and is equivalent to inflorescence number. Nearest neighbor data were also collected for five of the 19 plants observed in the native population. Six, 60 cm \times 60 cm quadrats were placed around areas containing *A. grandiflora* and specific plant cover estimates were taken. Five 60 cm \times 60 cm areas were randomly selected within the historic *A. grandiflora* population area for additional cover estimates in areas not containing *A. grandiflora* plants this year.

A-2.3.1. Estimate of Nutlet Production

The number of nutlets produced by the native populations and the FL and FF experimental subpopulations were estimated using previously developed regression equations. The number of nutlets per plant in the native population was estimated using the regression equation, # nutlets/plant = 3.42*(shoot length in cm)-65.46, $r=0.86$, $p<0.01$ (Pavlik, 1991). The number of nutlets per plant in the experimental population was estimated using the regression equation, # nutlets/plant = 16.81*(# of inflorescences)-36.76, $r=0.96$, $p<0.0001$ (unpublished). If the estimated seed production for an individual plant was a negative number, it was defined as zero.

A-2.3.2. Analysis of Nearest Neighbor Data

The frequency of nearest neighbor species and Shannon's Index (H') were calculated for the Native, FL, and FF populations using the formula $H' = -\sum_{i=1}^S (n_i/n) * \ln(n_i/n)$, where S is number of different species observed as nearest neighbors, n is the number of individuals observed, and n_i is the number of individuals in the i th species. (Shannon and Weaver, 1949). This diversity index is an expression of the likelihood that two plants picked at random will be of two different species. So, it not only reflects the number of species present in the sample, but also gives an idea of the evenness of distribution for these species (Ludwig and Reynolds 1988). The higher the number of species and the more evenly they are distributed, the higher the diversity index.

A-2.3.3. Analysis of the Cover Estimates

Cover data were analyzed by calculating constancy, mean cover and Importance Value for each species as well as for thatch and bare ground. Constancy was calculated by dividing the number of times any one species was observed in a plot or area (referred to as the count) by the total number of plots for that year. Mean cover was calculated by averaging the cover over all plots where each species was found. Importance Values (I.V.) for each species was calculated by summing the constancy and mean cover value by species.

A-2.3.4. Analysis of *Amsinckia* Counts in the FF Subpopulation

A chi-square test was used to compare the number of *A. grandiflora* present in plots of different burn frequencies in 2002. The chi-square value was estimated using the log-likelihood ratio, G (Zar, 1984). Because the first treatment burn in the FF subpopulation occurred in July of 2001, there were only two categories of burn frequencies at the time of the 2002 spring census: those not burned in 2001 (the 5 control plots), and those burned in 2001 (the remaining 15 low, medium, and high frequency plots). The actual distribution of *Amsinckia grandiflora* in burned and unburned plots was compared to the distribution that would be expected if *A. grandiflora* were evenly dispersed throughout all plots. With an even distribution, 25% of the *A. grandiflora* observed are expected to be in the control plots and 75% are expected to occur in the remaining plots.

A-2.4. *Poa secunda* Persistence

Perennial bunch grasses were counted in both the FF and FL subpopulations on 27 Mar 02 at time of bunchgrass flowering to monitor long-term establishment of *Poa secunda*. For the FL subpopulation, differences in *Poa* densities over burn treatments and 1993 planting regimes were analyzed using the general linear model. PROC GLM in SAS (SAS, 1990) was used for data to 2001, lm in R (R Development Core Team, 2003) was used for 2002 data. Analysis of *Poa* counts in the FF subpopulation were done using the same methods described above for FF *A. grandiflora* counts.

A-2.5. Biomass

Biomass samples ($0.1m^2$) were collected from the center of ten FL plots on 31 May 02. These plots were selected using a randomized block design. Biomass was collected from five sample plots from the area that was burned in 1999 and five sample plots from the unburned area. These

plots are shown on Figure A4 as “B”. Biomass samples (0.1m²) were also taken above each plot, where biomass samples were taken, in the first three rows of the FL population. No biomass samples were taken from the native population.

Differences in biomass amounts over burn treatments were analyzed using the general linear model: *lm* in R (R Development Core Team, 2003). Raw data for forb biomass did not meet the assumptions of the test until it was log transformed. Analysis was performed on raw data for grass, thatch and total biomass and on transformed data for forb biomass.

A-2.6. Predation Monitoring

Each year, *A. grandiflora* nutlets are set out to monitor levels of seed predation within the experimental population. A single nutlet is adhered with double-stick tape to each of 25 3.5-inch galvanized nails spaced 10 cm apart in five rows of five nails. Each nail is pressed into the soil so the nail head is flush with the soil surface.

Predation monitoring was conducted in two rounds. Round one was conducted before the prescribed burn in the FF population and round two was conducted after the FF burn. For round one, ten 100-cm² grids of nutlet/nails were placed using a randomized block design. Five grids were located in the FL plots and five were located in the FF plots (Figure A4). Round 1 nutlet/nails were placed into the plots on 5 May 02. Nails were checked on 8 May, 10 May, 14 May, 17 May, 24 May, and 31 May. On 31 May, all round 1 nutlet/nails were removed.

For round 2, ten nutlet/nail grids were placed into the FF subpopulation on 01 July 02. Five grids were located in unburned plots, and five grids were located in burned plots (Figure A4). Nails were checked on 2 Jul, 8 Jul, 12 Jul, 16 Jul, and 22 July. On 22 July, all round 2 nutlets/nails were removed.

Evenness was calculated to serve as an index of predator foraging effectiveness: if a plot had 5 or more nutlets missing, we considered it “discovered” by a granivore. Localization, or the percentage of plots with fewer than 5 nutlets remaining, was also calculated to serve as an indicator of forager effectiveness: how likely is it that a seed predator can almost completely denude a plot of nutlets?

Final predation percentages were not normally distributed and were compared among treatments using Kruskal-Wallis, a non-parametric ANOVA, in the NPAR1WAY procedure in SAS (SAS 1990). We used alpha = 0.05 for within-year, among-treatment tests of difference. FF and FL plots were kept separate in the analysis because of the possibility that the flashing still limited rodent granivore density and movement. Unplanned pairwise comparisons among years were performed using the Mann-Whitney U test. Since rounds of the experiment were of variable length, data were truncated at the three-week mark, and the cumulative predation percentage at that point was used as the final predation amount. Because data were only collected at weeks 2 and 4 in 1998, an average of these two percentages was used to estimate predation at the end of week 3. The final predation percentage in the burned plots of 2001 was used, even though that trial lasted only two weeks. Alpha for interyear comparisons was adjusted for multiple comparisons by the Bonferroni correction, resulting in an overall alpha of 0.005.

A-2.7. Lupine Study

The lupine study was initiated in the fall of 1999 to investigate the potential effects of *Lupinus albifrons* expansion on the biomass accumulation of *A. grandiflora* competitors. In previous years, *L. albifrons* and dying *L. albifrons* in the native population were mapped and presented graphically. In 2002, the extent of *Lupinus albifrons* invasion of the native population was recorded with a photograph.

A-3. Results and Discussion

A-3.1. Spring Census

Amsinckia grandiflora population sizes remain small. Nineteen plants were found in the Native population, with six of these plants occurring in the Carlsen-Gregory subpopulation (Table A1). Figure A5 shows the general locations of *A. grandiflora* plants observed in the native Drop Tower population in 1998–2002. The Native population has contained less than fifty plants each year for the last four years (Figure A6). As can be seen in Figures A7 and A8, numbers of individuals observed in the FL and FF subpopulations have also remained low in recent years. The number of *A. grandiflora* in both Site 300 experimental subpopulations decreased in 2002 compared to 2001 numbers. Ten plants were observed in the FL subpopulation in 2002 compared to 59 plants in 2001 (Figure A7). The FL population had its largest population in 1996 when 720 plants were observed. Fifty-seven plants were observed in the FF subpopulation in 2002 compared to 257 plants in 2001 (Figure A8). The distribution of *A. grandiflora* in the FL subpopulation in 2001 and 2002 is shown in Figure A9. Plants in both parts of the experimental population were very small in size (approximately 15 cm average height). Plants in the native population had an average height of 26 cm which is the tallest average height since pre-1999 (Table A1).

The average number of inflorescences per plant was approximately one for the FL and FF experimental populations and 1.5 for the native population. The number of inflorescences per plant was also one in the FF and FL populations in 2001 (Table A1). The number of nutlets produced by the native population in 2002 is estimated to be 188 based on the height of the plants (Table A1). Using a regression equation developed in 1994 (unpublished data), it would appear that the FL and FF subpopulation produced no nutlets in 2002 (Table A1).

When examining population sizes from Draney Canyon, the Drop Tower native population, and the Drop Tower experimental population (Figure A10), it appears that numbers remained stable or increased in the years 1986 to 1996. After 1996, the numbers of all three populations dropped. Draney Canyon had no plants in 1998–2000 and was not surveyed in 2001 or 2002. While it appears that high rainfall years are detrimental to *A. grandiflora* populations, the effect is either delayed or dependent on multiple years of high rainfall in close proximity.

A-3.1.1. Analysis of *Amsinckia* Counts in the FF Subpopulation

The distribution of *A. grandiflora* in the FF subpopulation was compared to the distribution that would be expected if the plants were evenly distributed. The distribution of *A. grandiflora* differed significantly from the even distribution ($G = 20.65$, $p < 0.001$). The average number of *A. grandiflora* was higher in the unburned plots (5.6 plants) compared to the burned plots (1.5 plants).

A-3.1.2. Nearest Neighbor Data

Composition of nearest neighbors probably overemphasizes the importance of small, understory plants, but since data collection methods have remained the same over the years, these data are useful in making comparisons among subpopulations and years. Table A2 shows the percent species composition of *A. grandiflora* nearest neighbors for both native and experimental populations. Shannon's index of diversity is also shown.

The exotic species *Erodium cicutarium*, *Avena* spp. *Bromus diandrus*, and *Bromus hordeaceus* have consistently been among the most common nearest neighbors (FF and FL). Another exotic grass, *Vulpia myuros*, did not occur as a nearest neighbor in native population in 1997–1999 but has been a nearest neighbor in the experimental population since 1999 and appeared as a nearest neighbor in the native population in 2000. Presence of *E. cicutarium* as a nearest neighbor is similar to *V. myuros* in that it was an uncommon nearest neighbor in the native population 1997–1999 but appeared in the experimental population in 1999 and became more common as a nearest neighbor in the native population in 2000. The presence of native forb and grass species as nearest neighbors in the experimental and native populations, such as *Galium aparine*, *Achillea millefolium* and *Poa secunda*, has been much more variable. *Galium aparine* has followed the opposite than *V. myuros*; It was more common as a nearest neighbor in the native population in 1997–1999 and less common in other locations and in later years. *Collinsia heterophylla* appears similar to *G. aparine*, with the exception of a high frequency in 2001 FL plots.

The diversity index for all locations was lower in 2002 than it was in 1997, 1998, 2000 and 2001. In 1997, 1998, 2000, and 2001, the diversity index was high (1.8 or above) for all locations (Table A2). In 1999, the diversity indexes (1.31 for the native population and 1.59 for the FL experimental population) were similar to the 2002 diversity indexes (1.39 for the native population and 1.43 for the FL experimental population). The 2002 and 1999 diversity indexes are also similar in that of the four years for which Shannon's diversity index has been calculated for the native and experimental populations, 1999 and 2002 are the only years in which the diversity index was higher for the experimental FL subpopulation than for the native population. FF plots had a lower diversity index in 2000 than the other two locations but a higher index in 2001 and 2002. The lower index in 2000 may have been due to the extreme disturbance the plots suffered over the previous winter during plot establishment. This is also compounded by low sample size in recent years, as data are only collected when an *A. grandiflora* plant is present.

A-3.1.3. Cover Estimates

Due to the overemphasis on understory plants in nearest neighbor data, cover estimates were also taken for the three locations in 2001 and 2002. In 2002, *Avena* spp. had among the highest I.V.'s for all three locations (Table A3). In the FF subpopulation, three species (*Avena* spp., *Erodium cicutarium* and *Poa secunda*) tied for the highest I.V. (1.2) and *Vulpia myuros* and *Lupinus bicolor* ranked second and third respectively. In the FL subpopulation, the species with the highest-ranking I.V.'s were similar to high-ranking species in the FF subpopulation. *Erodium cicutarium* and *Avena* spp. both tied for the highest I.V., and *Vulpia myuros* and *Erodium cicutarium* ranked second in FL subpopulation. In the native population, *Avena* spp., *Bromus hordeaceus*, and *Delphinium hesperium* ranked first, second, and third respectively. That *P. secunda* ranked among the highest I.V.'s for FF plots is no surprise, given their design. Bare

ground had the greatest mean cover in the FF plots (26.0%) and the least in the native plots (11.4%). Thatch ranged from an average of 12.3% in the FF plots to 30.0% in the native plots. Thirty different species were recorded from all three locations in the cover estimates for 2002, and less than half were recorded in nearest neighbor data from that same year. While this is partially due to the constraint that there can only be as many data points as there are *A. grandiflora* plants for nearest neighbor data, it may also be due to the fact that the closest plant to any given *A. grandiflora* is most often an understory plant such as *E. cicutarium* rather than a larger plant like *Lupinus albifrons*.

A-3.2. Biomass Collection

Although total biomass in the FL subpopulation gradually declined from 1998 to 2001, there was an increase in biomass in 2002 (Table A4, Figure A11). Biomass samples collected from the FL subpopulation were slightly higher in 2002 than 2001 for grasses, herbs, and thatch and slightly lower in 2002 than 2001 for *Poa*, although *Poa* biomass was very low (less than 1%) during both years (Figure A2). There was a significant difference ($p < 0.5$) in herb biomass in burned versus unburned plots in 2002, but not in any of the other biomass categories. Total average biomass, for burned and unburned plots, in 2002 was about 20 g/0.1m² which is almost double the 2001 average biomass was of 11 g/0.1m². In both 2002 and 2001, there was little difference between total biomass in burned and unburned plots (Figure A11). Total biomass in 1999 and 2000 was close to 20 g/0.1m² in unburned plots and approximately 10 g/0.1m² in burned plots. Biomass was much higher in 1998 at around 30 g/0.1m² for burned plots and 20 g/0.1m² in unburned plots. “Burned” plots have not been burned since 1999, so it is possible that this lack of difference between the two plot types in 2001 and 2002, particularly for thatch (a variable for which the two areas have traditionally been different in the past), is due to that factor.

Biomass samples were taken above five FL plots in addition to samples taken within plots to determine if work within the plot affects biomass. Higher biomass from samples taken above the plots would indicate that the monitoring and research that is done within these plots is reducing biomass. The average biomass for the above plot samples is 22.67 g/0.1m² compared to an average biomass of 18.68 g/0.1m² taken from within the corresponding existing five plots. Although the means biomass above plot is slightly higher than the biomass within plots, a 2-sample t-test shows no significant difference ($p = 0.25$) between these means.

We expected that the continual drop in biomass prior to this year would signal a resurgence in *A. grandiflora* numbers in 2001 in response, but this was not the case. Numbers of *A. grandiflora* were lower in 2002 as would be predicted by the increased biomass.

A-3.3. *Poa secunda* Persistence

Accurately measuring the amount of *P. secunda* biomass has historically been problematic. The lack of perennial grass biomass in unburned plots is never confirmed in the counts of *P. secunda* made earlier in the season. For analysis of *P. secunda* persistence and density, early spring counts are more reliable than mid-spring collections of biomass.

Nine-year persistence of *Poa secunda* in the FL plots is shown in Table A5. Until 2000, there was no difference in *Poa* densities between burned and unburned plots. In 2000, after two consecutive years of burning, there appeared to be a difference in *P. secunda* concentrations between burned and unburned plots ($p = 0.017$). In 2000, effects of starting *P. secunda* density

and differences among planted, existing, and *P. secunda*-removed plots disappeared ($p = 0.5$ for both). In 2001, when two years had passed since the last burn, the effects of the burn were not significant for *P. secunda* density ($p = 0.09$). In 2001, effects of starting densities and plot type (existing, planted, and *P. secunda*-removed) remained nonsignificant ($p = 0.56$ and 0.22 , respectively).

In 2002, there was a significant interaction between starting density and plot type ($p < 0.05$). Planted *Poa* plots had higher densities than plots where existing *Poa* plants were used. Planted *Poa* plots kept the relative scaling of high, medium, and low densities, but plots with existing medium densities in 1993 ended up with the lowest densities in 2002. In 2002, there was no effect of burn on *Poa* densities. Thus, the only significant difference in *Poa* densities within the FL plots occurred in 2000, after two consecutive years of burning.

The FF plots were originally established in 1999 with 33 *P. secunda* per plot for all fire frequencies. In 2000, the number of *P. secunda* stayed high in all plots (average of 29 *P. secunda* per plot), but in 2001, the number of *P. secunda* per plot was much lower (average of 22 plant per *P. secunda* per plot) (Table A6). In the summer of 2001 after *Poa* counts were completed, FF burns began. All plots except the control plots were burned in 2001. In the FF subpopulation, the overall average number of *Poa* plants per plot increased to 27 in 2002. The distribution of *Poa* plants in FF plots in 2002 differed significantly ($G = 10.73$, $p < 0.005$) from the distribution that would be expected if *Poa* plants were evenly distributed in unburned (control) and burned (low, medium and high frequency) plots. There was an average of 20.6 *Poa* in the unburned plots and 29.1 *Poa* in the burned plots.

A-3.4. Predation Study

In the four years where seed predation in burned and unburned areas were compared, predation in the burned plots was always statistically equal to or higher than predation in the unburned plots (Table A7). Figure A13 shows that predation in 2002 was much higher in burned plots, reaching 100% predation by day ten, compared to all other groups of unburned plots, none of which had greater than 50% predation throughout the monitoring period. Generally, burning makes seeds more available to seed predators, and burning places *A. grandiflora* at greater risk of seed loss.

In most years, seed predators were able to find all plots where seed was placed for the experiment (evenness equal to 100%). However, this did not automatically result in high overall seed predation. While in most trials all plots were found, in many trials plots were not completely devoured (localization less than 80%). The large-scale spatial pattern of foraging does not appear to change among years (almost all plots found in all years), but the small-scale pattern of seed foraging (within-plot seed discovery) does change among years. When small-scale foraging is less effective, a significant number of *A. grandiflora* seeds may remain to serve as a population source for subsequent years.

In 2001, granivores were less effective in denuding plots of seeds compared to previous years. We predicted that because of the increase in seed resources for the population to draw upon, *A. grandiflora* population numbers would be higher in 2002 than 2001. This was not the case, and clearly the relationship between *A. grandiflora* and its environment is more complex than a simple numerical population response to the previous year's seed predation. Predation in open, unburned areas remained low in 2002, but, after the burn, every single seed in open, burned plots was eaten. Additionally, after the burn, granivory rates between the open, unburned plots in the Flashing and

Fire Frequency areas were significantly different ($p = 0.04$). Predation rates in the Flashing area tend to be lower than those in the Fire Frequency plots, indicating that the flashing may still have some effectiveness in excluding rodents.

Because of the extremely high rates that we have observed in some years, seed predation is very likely a significant factor in determining *A. grandiflora* population sizes. We will continue to monitor seed predation to try and determine the relationship between predation, rainfall and previous year's population size on the population dynamics of *A. grandiflora*.

A-3.5. Lupine Study

In 2001, we began monitoring the *Lupinus albifrons* photographically. Prior to 2002 *L. albifrons* in the native population was also counted and mapped using an established grid and topographic maps. Photographs are now being used to monitor *L. albifrons* distribution because they provide an easy and accurate method of recording the number and distribution of this species with less disturbance to the site. Figure A14 shows a photograph of the native population in the spring of 2002 compared to the spring of 2001. Although the 2002 picture was taken before the trees and shrubs at the site had begun to grow the new foliage for the year, and the 2001 photograph is slightly later in the season, careful examination of the photographs shows that the extent of *L. albifrons* is similar in 2001 and 2002. In 2001, of the 42 *L. albifrons* that were mapped in 1999, 19 were dead or dying and 14 newly recorded. The photographs show that approximately 42 lupines were still present in 2002 and that the 2002 distribution of *L. albifrons* is similar to 2001 distribution. Included among those lupine that are dying is the large shrub that was the only *L. albifrons* apparent within the *A. grandiflora* population in the late 1980s and early 1990s. This ancestral *L. albifrons* is circled in blue on Figure A14.

A-4. Recommendations and Future Work

Population numbers at both the native and experimental Drop Tower locations remain low. In 2002, the estimated seed production for the native and experimental site was again very low as in was in 2001. Each additional year that passes without replenishing the existing seed bank in the soil puts the population in greater risk of not being able to sustain itself naturally. Biomass in the FL subpopulation was higher in 2002. The associated competition from neighbor biomass may be contributing to the low number of plants. In 2001 and 2002, we had hoped that the decrease in seed predation would foreshadow an increase in *A. grandiflora* numbers in 2001. We will continue to monitor above-ground competition by collecting biomass samples yearly and will continue to monitor seed predation pressure. Long-term data on these variables, combined with *A. grandiflora* fecundity estimates and meteorological data will be combined to establish an algorithm to predict population vigor and to inform management practices.

Photographs of the site show that the distribution of *Lupinus albifrons* in 2002 is similar to the 2001 distribution. Anecdotal evidence has indicated that *L. albifrons* goes through establishment pulses and catastrophic diebacks, but it is possible that the large-scale *L. albifrons* retreat from the *A. grandiflora* population area that we had hoped for has not begun as yet. We have begun to take a photograph every year from the other side of the canyon to monitor lupine population dynamics and will continue to do so. Because population numbers are critically low in the native population the manual removal of *L. albifrons* from this population may become necessary in the future. In

addition, annual grasses and thatch may be manually reduced in the native population in an attempt to increase number of *A. grandiflora* that survive to flowering. It may also be necessary to control grass competition, lupine expansion and predator pressure to ensure persistence of the populations, particularly during the early establishment phase of experimental populations.

The number of *A. grandiflora* in the FF population sharply decreased in 2002, and *A. grandiflora*'s small plant size and resultant reduced fecundity remains a concern in this subpopulation. While the FF plots will be burned relatively often and this will probably control competitor biomass, if poor *A. grandiflora* years continue, we may be forced to continually supplement this subpopulation's seed bank or explore other strategies to maximize *A. grandiflora* success. After the first year of burn treatments in FF subpopulation, a difference in the *Poa* and *A. grandiflora* distribution between the burned and unburned plots was observed in 2002. A higher number of *Amsinckia* and lower number of *Poa* were observed in the unburned plots compared to the burned plots.

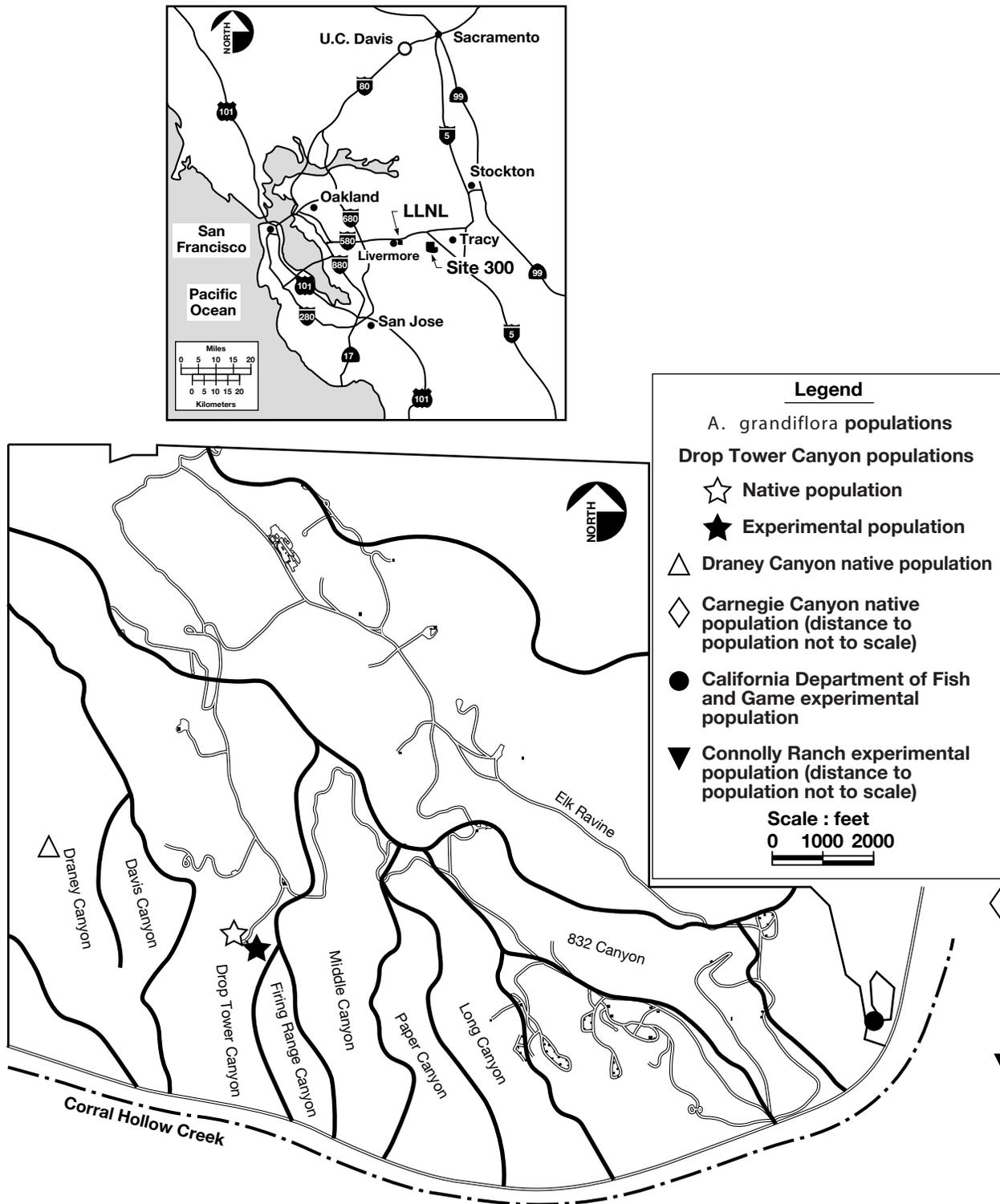
In 2002, the number of *A. grandiflora* in the FL population was the lowest it has been in the last ten years. A seed bank enhancement project is currently (FY 2003) being conducted in the FL subpopulation and another experimental population at Lougher Ridge in Black Diamond Mines Regional Park in attempt to boost these populations.

A-5. References

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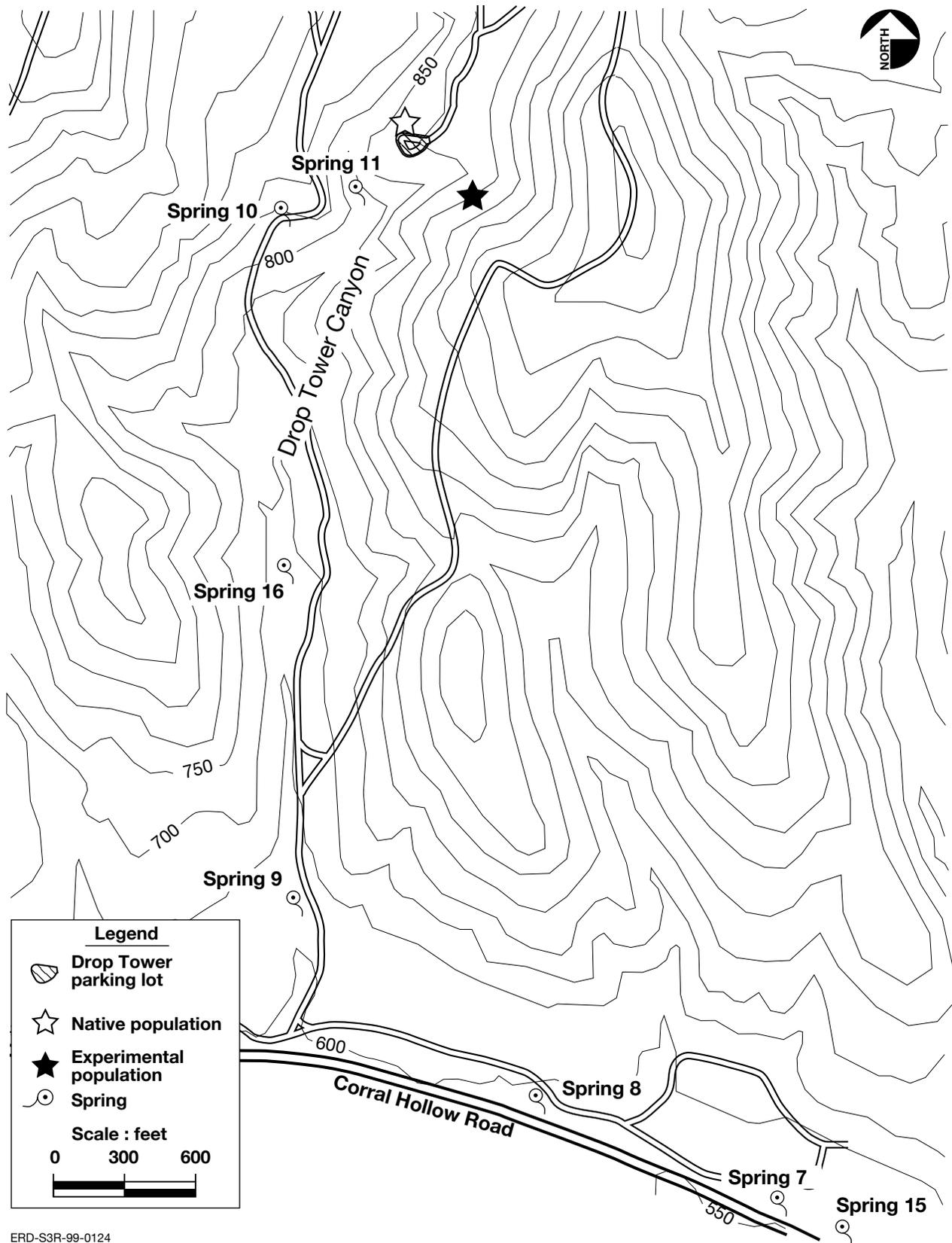
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Section A
Figures



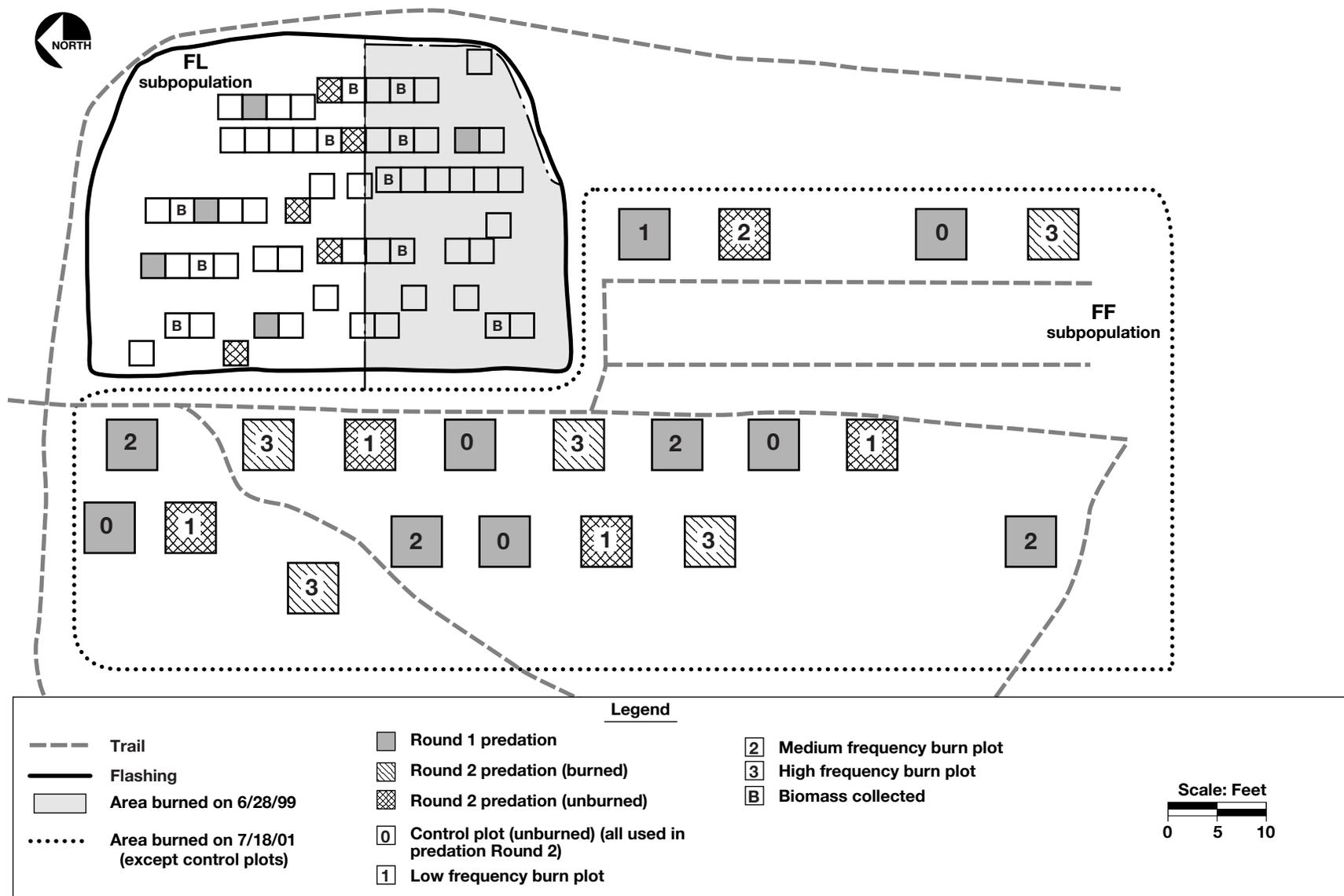
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Figure A2. Locations of *Amsinckia grandiflora* populations at or near Lawrence Livermore National Laboratory (LLNL) Site 300.



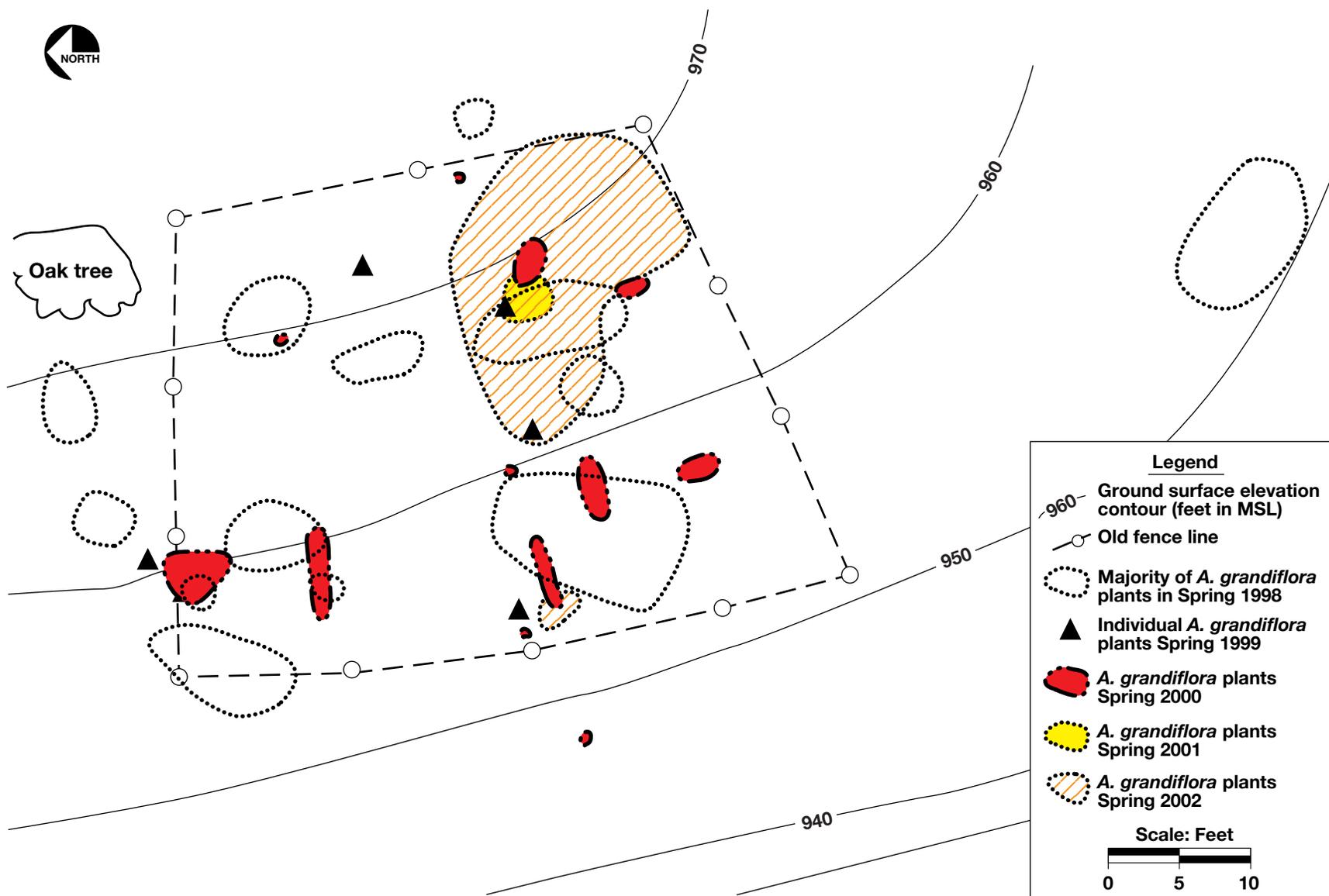
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Figure A3. Location of native and experimental *Amsinckia grandiflora* populations in Drop Tower Canyon.



ERD-S3R-03-0150

Figure A4. Summary of experimental treatments at the experimental *Amsinckia grandiflora* population.



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Figure A5. Spring census of the *Amsinckia grandiflora* native Drop Tower population: 1998–2002.

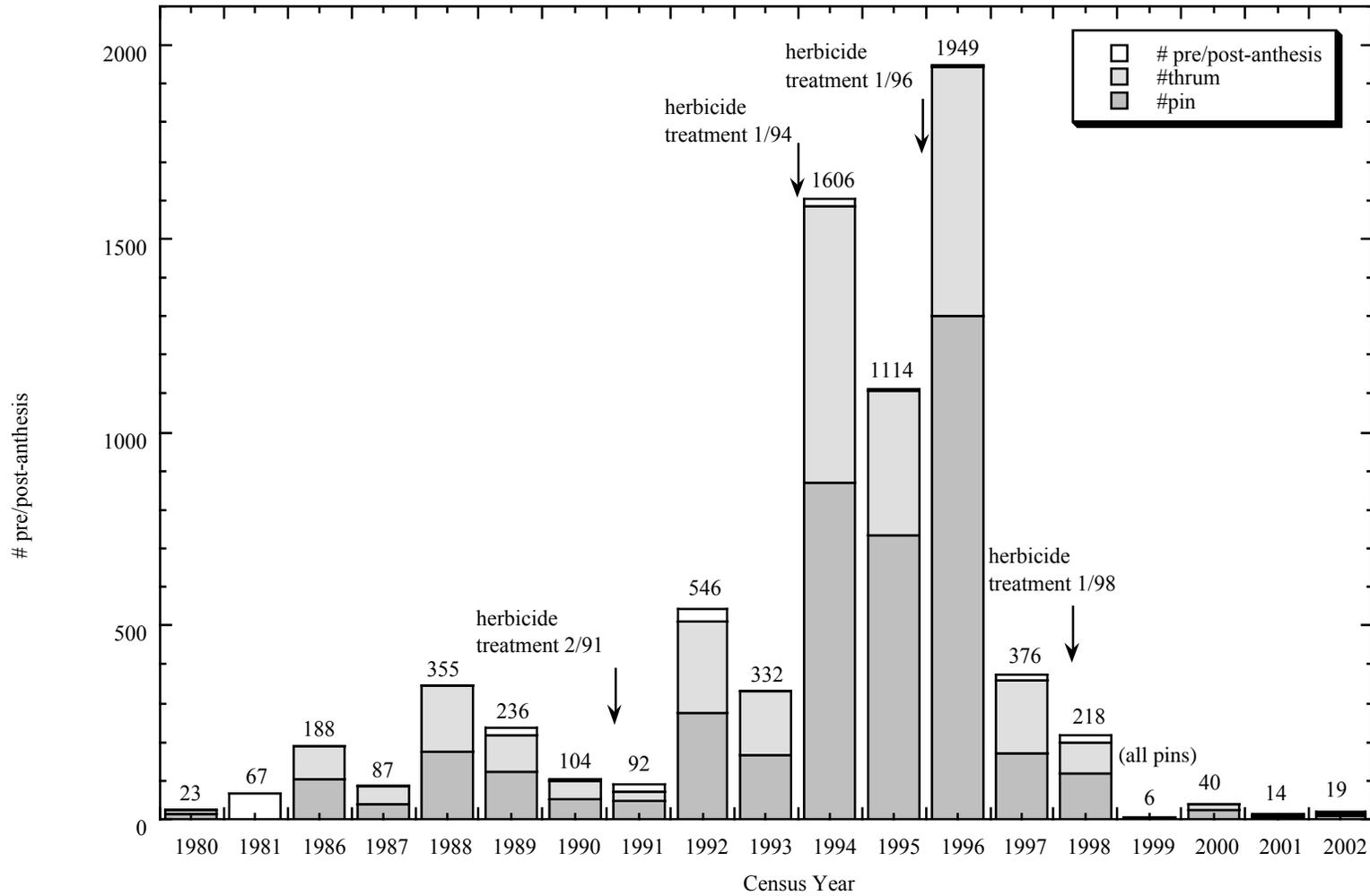


Figure A6. Historical spring census data of the Site 300 Native Drop Tower population. Total population size is given above each bar. Approximate timing of herbicide treatments is shown.

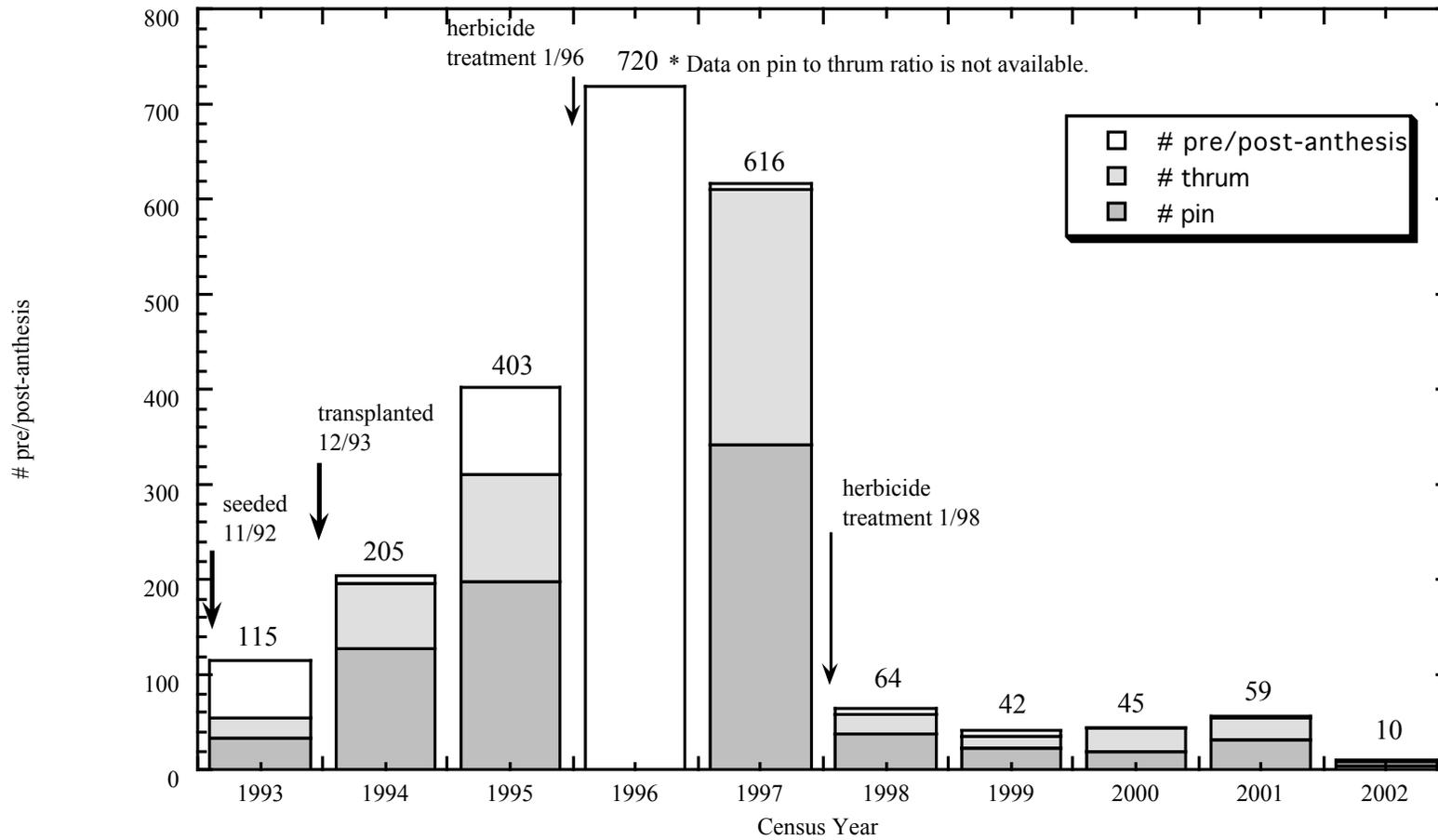


Figure A7. Historical spring census data of the Site 300 experimental FL subpopulation. Total population size is given above each bar. Approximate timing of all treatments is shown.

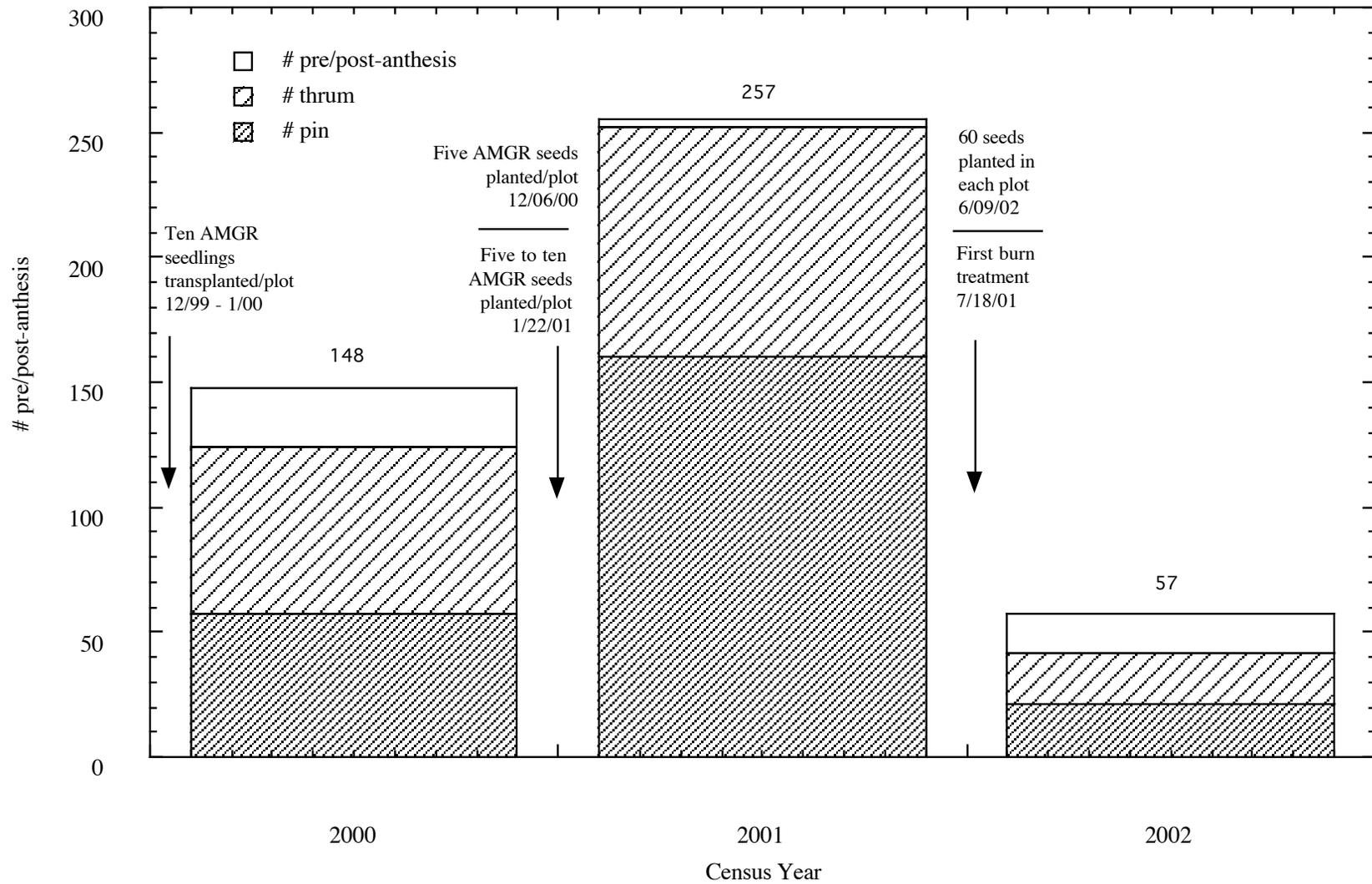


Figure A8. Spring census data of the Site 300 experimental FF subpopulation. Total population size is given above each bar.

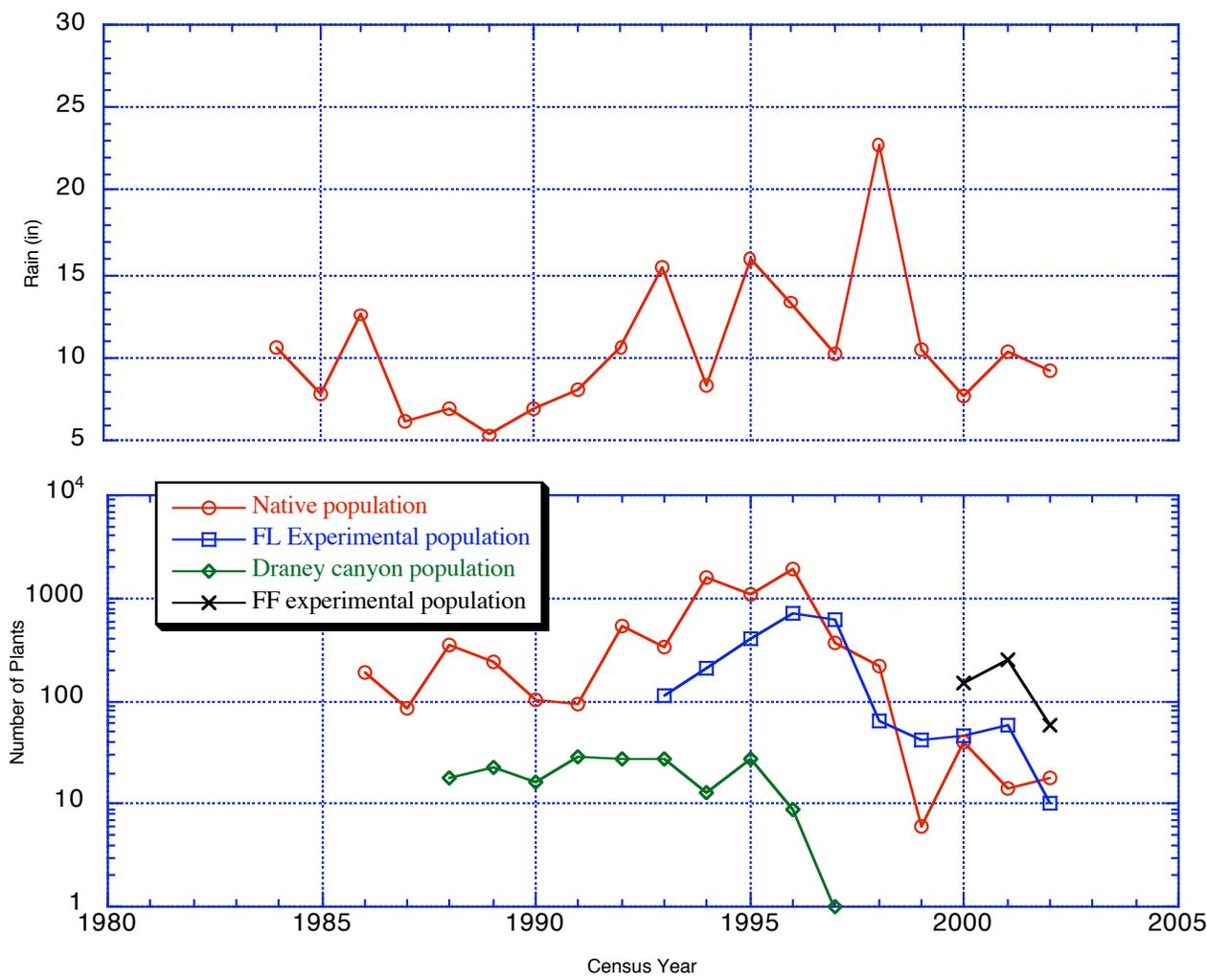


Figure A10. Log plot of population size at time of census, shown with rainfall totals over growing season.

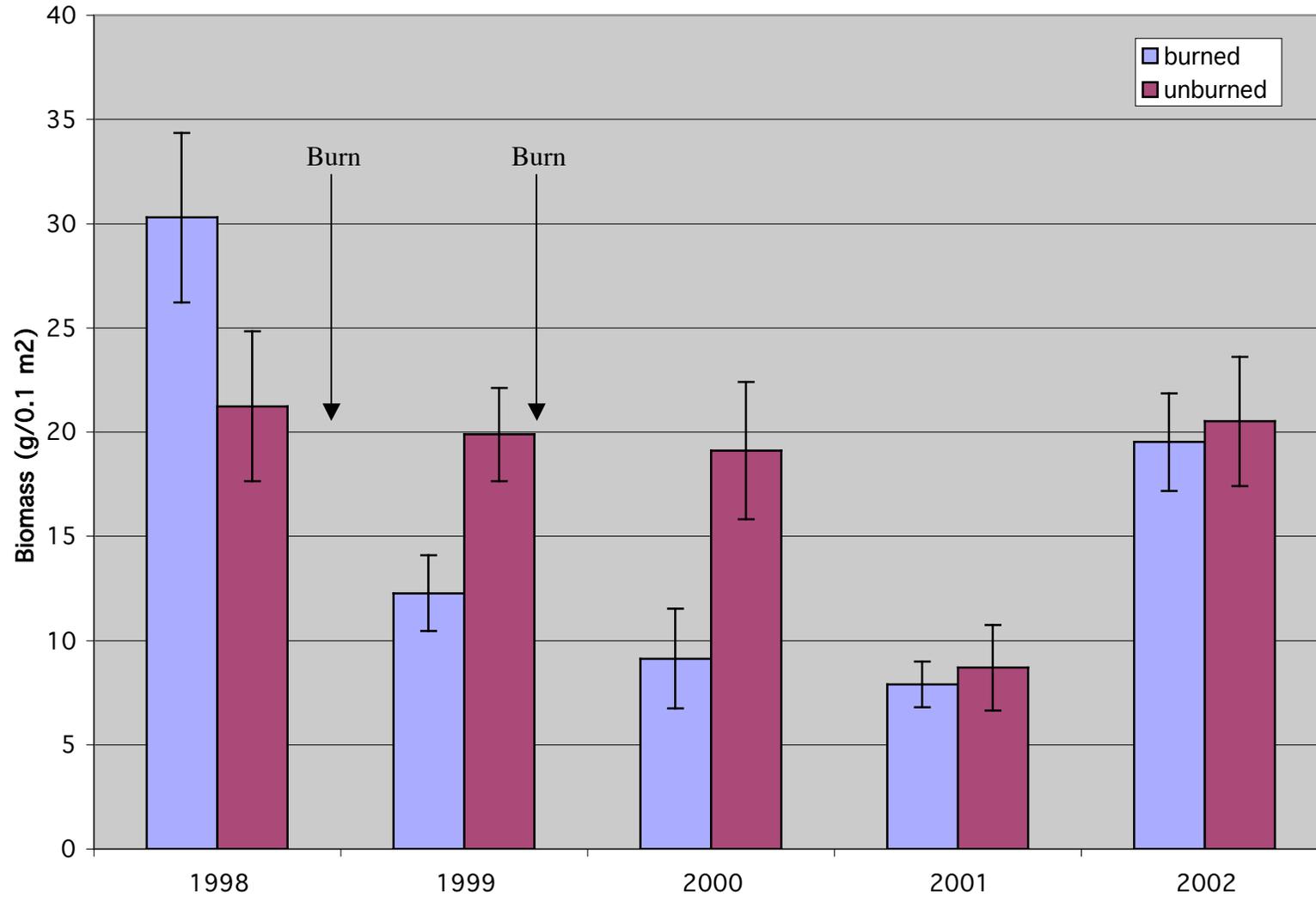


Figure A11. Total biomass in FL plots burned in 1998 and 1999 vs. FL plots not burned. Error bar represent ± one standard error.

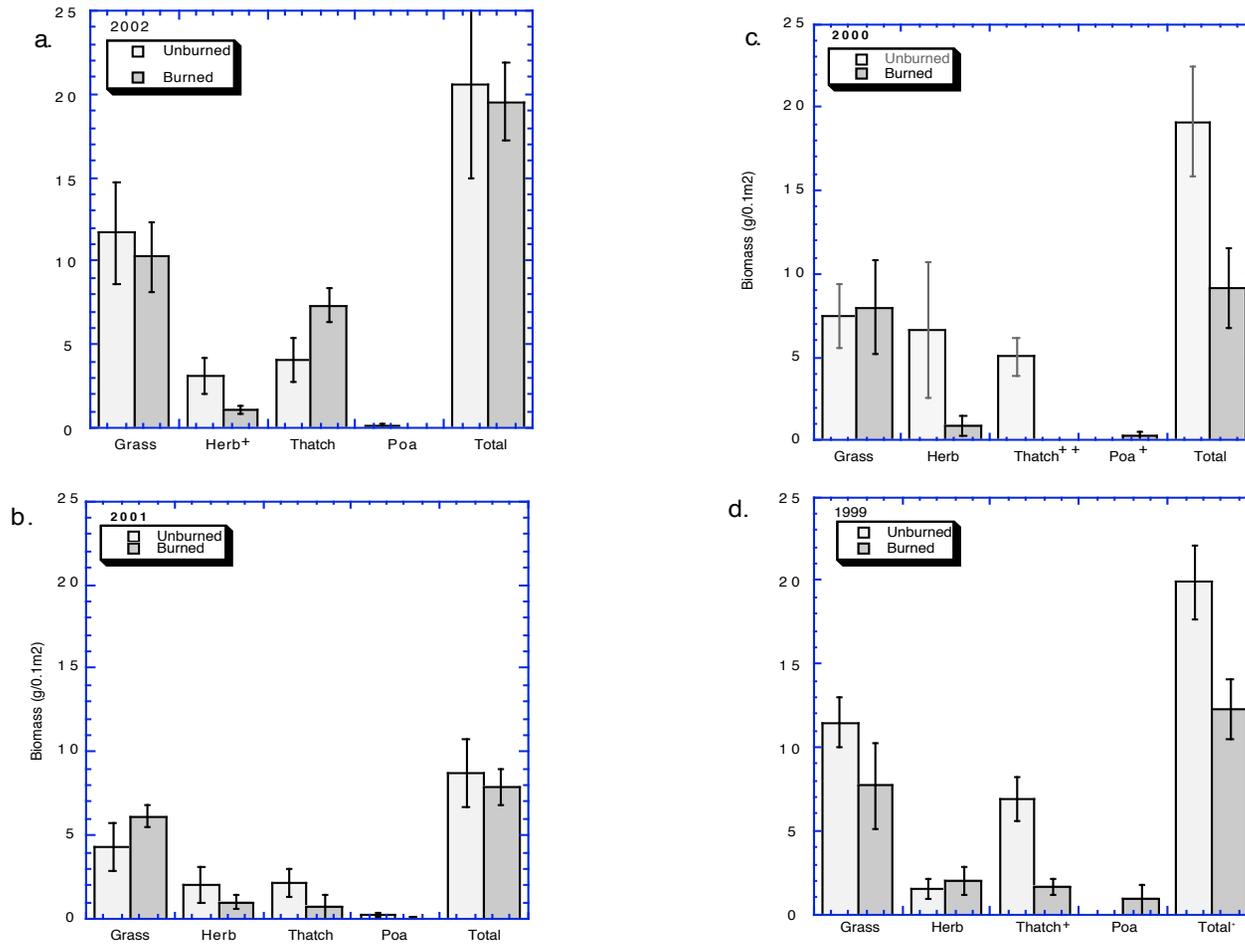
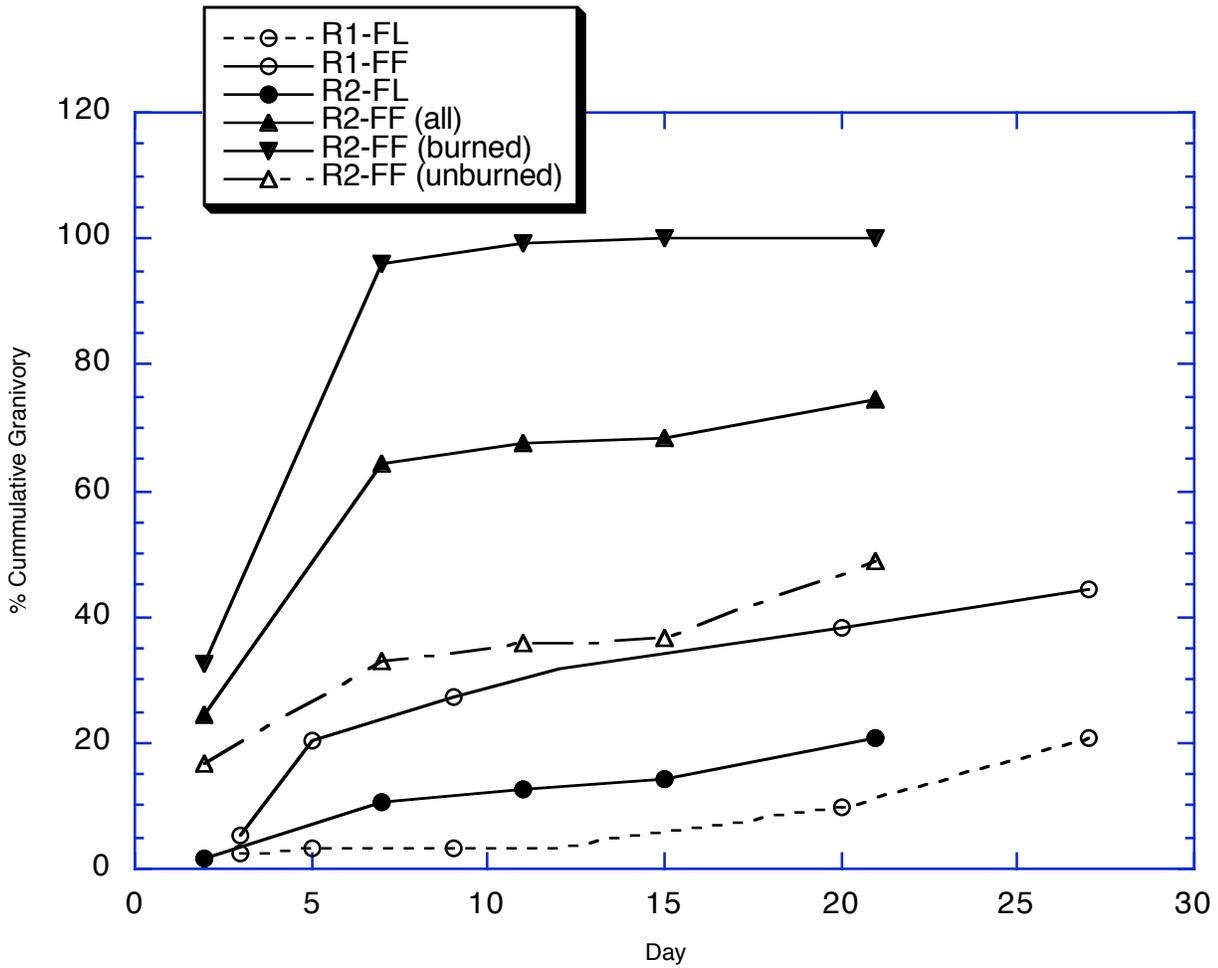


Figure A12. Biomass of burned vs. unburned FL plots. Bars are one standard error. ++ indicates treatments differ at $p < 0.01$. + indicates treatments differ at $p < 0.05$. $n=5$. a) 2002 data, b) 2001 data, c) 2000 data, d) 1999 data. (The last burn of the FL population was conducted in 1999.)



Notes:

Round 1 (R1) started on 5/8/02 and ended on 5/31/02.

Round 2 (R2) started on 7/3/02 and ended on 7/22/02.

In round 1, both subpopulations were unburned.

FL = Flashing Subpopulation

FF = Fire Frequency Subpopulation

Figure A13. Cumulative percent granivory in 2002 by treatment and burn.



2001



2002

Figure A14. Native population in spring 2001 and 2002. Small shrubs are *Lupinus albifrons*. The native population is outlined in red, and the original *Lupinus albifrons* is outlined in blue.

Section A
Tables

Table A1. Summary of demographic data collected from the Site 300 Drop Tower experimental and native populations. All averages are \pm one standard error.

Population	Total no. of plants	P/T ratio ^a	Average height (cm)	Average no. of branches per plant ^b	Estimated average seed production per plant ^c	Estimated total seed production per population ^d
<i>Spring 1999</i>						
Native	6	all P	15.30 \pm 2.98	1.0 \pm 0	0	0
FL plots (experimental)	42	2.18	13.30 \pm 0.83	1.0 \pm 0.02	0	0
<i>Spring 2000</i>						
Native	40	2.16	20.13 \pm 0.75	1.70 \pm 0	10.92 \pm 2.31	436.98
FL plots (experimental)	45	0.76	16.78 \pm 0.84	1.32 \pm 0	2.70 \pm 1.62	121.92
FF plots (experimental)	148	0.85	16.67 \pm 0.50	2.33 \pm 0	10.54 \pm 1.70	1560.85
<i>Spring 2001</i>						
Native	14	0.43	17.21 \pm 1.14	1.0 \pm 0	2.60 \pm 1.29	36.40
FL plots (experimental)	59	1.29	13.67 \pm 0.69	1.0 \pm 0	0	0
FF plots (experimental)	257	1.74	15.74 \pm 0.29	1.02 \pm 0.01	0.11 \pm 0.08	28.27
<i>Spring 2002</i>						
Native	19	1.14	24.69 \pm 4.83	1.50 \pm 0.56	9.93 \pm 2.62	188.7
FL plots (experimental)	10	1.67	15.78 \pm 2.26	1.0 \pm 0	0	0
FF plots (experimental)	57	1.00	15.15 \pm 0.85	1.05 \pm 0.04	0	0

Notes:

FL = Flashing subpopulation.

FF = Fire frequency subpopulation.

^a Calculated using the number of pin versus thrum plants in the entire population. Does not include plants that were senescent or had not flowered at the time of the census.

^b In the native population, branch number was defined as the number of stems branching from the main stem. In the experimental population, branch number was defined as the number of inflorescences per plant.

^c The number of nutlets per plant in the native population was estimated using the regression equation, # nutlets/plant = 3.42*(shoot length in cm)-65.46, $r=0.86$, $p<0.01$ (Pavlik 1991). If the estimated seed production for an individual plant was a negative number, it was defined as zero. The number of nutlets per plant in the experimental population was estimated using the regression equation, # nutlets/plant = 16.81*(# of inflorescences)-36.76, $r=0.96$, $p<0.0001$ (unpublished). If the estimated seed production for an individual plant was a negative number, it was defined as zero.

^d Total seed production per population was estimated by multiplying the average seed production per plant by the total number of plants in the population.

Table A2. Species composition of *Amsinckia grandiflora* nearest neighbors at the Drop Tower Native and Experimental (Exp) populations: 1997–2002.

Species	Native 97 (%)	Native 98 (%)	Native 99 (%)	Exp FL 99 (%)	Native 00 (%)	Exp FL 00 (%)	Exp FF 00 (%)	Native 01 (%)	Exp FL 01 (%)	Exp FF 01 (%)	Native 02 (%)	Exp FL 02 (%)	Exp FF 02 (%)
<i>Achillea millefolium</i>	5	5	–	–	5	–	–	–	–	–	–	–	–
<i>Allium serra</i>	–	1	–	–	–	–	–	–	–	–	–	–	–
<i>Amsinckia grandiflora</i>	–	–	–	–	–	7	–	–	4	5	–	22.2	–
<i>Amsinckia tessellata</i>	–	–	–	–	3	5	–	–	4	1	–	–	–
<i>Amsinckia</i> sp.	–	–	–	–	–	–	–	–	–	–	12.5	–	–
<i>Astragalus didymocarpus</i>	–	–	–	–	3	–	–	–	–	–	–	–	–
<i>Avena</i> sp.	18	13	–	7	15	11	24	21	21	21	50.0	11.1	21.7
<i>Bromus diandrus</i>	22	9	17	5	5	2	2	14	2	16	12.5	–	–
<i>Bromus hordeaceus</i>	31	21	50	33	3	5	1	14	7	7	12.5	–	–
<i>Bromus madritensis</i> ssp. <i>rubens</i>	1	–	–	–	–	–	–	–	–	1	–	–	–
<i>Bromus</i> sp.	–	–	–	–	5	5	28	–	–	–	–	–	–
<i>Castilleja exserta</i>	–	–	–	–	–	–	–	–	–	1	–	–	–
<i>Clarkia</i> sp.	–	3	–	–	5	–	1	7	5	5	–	–	13.0
<i>Claytonia parviflora</i>	1	1	–	12	–	16	6	–	–	–	–	–	–
<i>Collinsia heterophylla</i>	3	9	17	–	–	–	–	–	–	1	–	11.1	–
<i>Delphinium hesperium</i>	1	3	–	–	3	2	–	–	–	–	–	–	–
<i>Erodium cicutarium</i>	4	5	–	24	18	16	4	21	41	21	–	44.4	21.7
<i>Galium aparine</i>	11	23	17	2	5	–	4	7	2	1	12.5	–	–
<i>Lithophragma affinis</i>	–	–	–	–	–	2	–	–	–	–	–	–	4.3
<i>Lupinus albifrons</i>	–	1	–	–	–	–	–	–	–	–	–	–	–
<i>Lupinus bicolor</i>	–	–	–	–	–	–	1	–	–	4	–	–	4.3
<i>Phacelia tanacetifolia</i>	–	–	–	–	3	–	–	–	–	–	–	–	–
<i>Poa secunda</i>	–	1	–	–	–	–	11	–	5	9	–	–	–
<i>Sonchus</i> sp.	1	–	–	–	–	–	–	–	–	–	–	–	–
<i>Vulpia myuros</i>	–	–	–	10	20	30	11	7	9	5	–	–	30.4
Unidentified dicot	3	3	–	7	8	2	2	7	–	2	–	–	–
Unidentified grass	–	–	–	–	–	–	–	–	–	–	–	11.1	4.3
# species (S)	12	14	4	8	14	12	12	8	10	17	5	5	7
n	100	129	6	42	39	45	151	14	56	244	8	9	23
Shannon's Index (H') ^a	1.92	2.16	1.31	1.59	2.40	2.14	1.93	1.97	1.80	2.35	1.39	1.43	1.68

Notes:

S is the number of species observed; n is the number of individuals observed; and n_i is the number of individuals in the i th species.

FL = Flashing subpopulation.

FF = Fire frequency subpopulation.

^a Shannon and Weaver (1949) $H' = -\sum (\text{of } i = 1 \text{ to } S) (n_i/n) * \ln(n_i/n)$.

Table A3. Constancy, percent mean cover for all plots in each subpopulation, and Importance Values (I.V.) for cover data collected from the Native and Experimental populations in 2002.

Species	Native (n = 11)				FL (n = 12)				FF (n = 20)			
	Constancy	Mean % Cover	SE	IV	Constancy	Mean % Cover	SE	IV	Constancy	Mean % Cover	SE	IV
<i>Achillea millifolium</i>	0.2	3.2	3.5	0.2	–	–	–	–	0.1	0.5	–	0.1
<i>Allium serra</i>	0.2	0.5	0.0	0.2	–	–	–	–	–	–	–	–
<i>Avena</i> sp.	1.0	30.0	3.8	1.3	1.0	26.04	4.83	1.3	1.0	21.0	3.8	1.2
<i>Amsinckia</i> sp.	0.1	0.9	–	0.1	0.7	5.00	2.95	0.7	–	–	–	–
<i>Amsinckia grandiflora</i>	0.5	1.4	0.6	0.5	0.4	1.04	0.00	0.4	0.7	3.0	0.9	0.7
<i>Bromus diandrus</i>	0.1	0.2	–	0.1	0.5	3.13	1.84	0.5	0.2	2.9	5.8	0.2
<i>Bromus hordeaceus</i>	0.8	12.5	2.6	0.9	0.5	5.00	3.08	0.6	0.7	3.8	1.5	0.7
<i>Bromus madritensis</i> ssp. <i>rubens</i>	0.9	6.4	1.9	1.0	–	–	–	–	–	–	–	–
<i>Castilleja exerta</i>	0.4	0.9	0.0	0.4	0.7	4.17	1.82	0.7	0.4	2.3	1.7	0.4
<i>Clarkia</i> sp.	0.5	1.1	0.0	0.5	0.7	4.38	1.42	0.7	0.7	2.4	0.8	0.7
<i>Claytonia</i> sp.	0.1	0.2	–	0.1	0.1	0.21	–	0.1	–	–	–	–
<i>Collinsia heterophylla</i>	0.6	1.6	0.0	0.7	–	–	–	–	0.1	0.1	–	0.1
<i>Delphinium hesperium</i>	0.7	4.1	1.4	0.8	0.3	0.63	0.00	0.3	0.3	1.1	1.7	0.3
<i>Dichelostemma capitatum</i>	–	–	–	–	0.2	0.42	0.00	0.2	0.1	0.3	–	0.1
<i>Erodium botrys</i>	0.2	1.1	5.3	0.2	–	–	–	–	–	–	–	–
<i>Erodium cicutarium</i>	0.6	9.1	2.5	0.7	1.0	30.00	3.21	1.3	0.9	25.3	4.4	1.2
<i>Galium aparine</i>	1.0	9.8	1.6	1.1	–	–	–	–	–	–	–	–
<i>Thysanocarpus curvipes</i>	0.1	0.2	–	0.1	0.3	1.46	2.17	0.3	–	–	–	–
<i>Lomatium</i> sp.	0.1	0.9	–	0.1	–	–	–	–	–	–	–	–
<i>Lupinus albifrons</i>	0.1	0.2	–	0.1	–	–	–	–	–	–	–	–
<i>Lupinus bicolor</i>	0.2	0.5	0.0	0.2	1.0	11.67	1.94	1.1	0.7	5.3	1.1	0.8
<i>Lupinus microcarpus</i>	0.3	3.6	2.0	0.3	–	–	–	–	–	–	–	–
<i>Lotus wrangellianus</i>	0.1	0.2	–	0.1	–	–	–	–	–	–	–	–
<i>Marah fabaceus</i>	0.1	1.4	–	0.1	0.1	1.25	–	0.1	–	–	–	–
<i>Poa secunda</i>	0.1	0.9	–	0.1	0.6	7.50	2.31	0.7	1.0	23.0	1.5	1.2
<i>Sonchus</i> sp.	–	–	–	–	–	–	–	–	0.1	0.1	–	0.1
<i>Blepharizonia</i> sp.	0.2	0.5	0.0	0.2	–	–	–	–	–	–	–	–
<i>Cirsium</i> sp.	–	–	–	–	–	–	–	–	0.1	0.3	–	0.1
<i>Vulpia myuros</i>	0.9	23.6	3.9	1.1	0.8	29.58	5.35	1.1	0.9	14.1	3.3	1.0
Unknown dicot	0.5	3.0	2.1	0.6	–	–	–	–	0.1	0.1	–	0.1
Bare	1.0	11.4	1.4	1.1	1.0	14.58	1.98	1.1	1.0	26.0	2.6	1.3
Thatch	1.0	30.0	3.4	1.3	1.0	16.25	3.33	1.2	1.0	12.3	3.9	1.1

Notes:

CALTEST = Caltest Analytical Laboratories, Napa, CA.

Constancy = Number of time a species occurs/total number of plots.

FF = Fore frequency subpopulation.

FL = Flashing subpopulation.

I.V. = Constancy + Mean Cover.

n = Number of plots.

SE = Standard error.

Table A4. Average dry biomass by dominant grass type in FL plots at the Site 300 Drop Tower experimental population.

Year	<i>Poa secunda</i> plots ^a		Annual grass plots ^b	
	Final dry biomass (g/0.1 m ²) ^c	<i>n</i>	Final dry biomass (g/0.1 m ²) ^c	<i>n</i>
2002	22.1 ± 1.50	5	16.6 ± 3.3	3
2001	7.3 ± 0.8	5	9.3 ± 2.1	5
2000	10.6 ± 2.9	5	17.6 ± 4.1	5
1999	13.5 ± 3.1	5	20.6 ± 8.2	5
1998	28.5 ± 2.2	6	21.7 ± 5.9	4
1994	9.9 ± 0.9	13	8.7 ± 0.9	20

Notes:

FL = Flashing subpopulation.

n = Number of plots.

^a Plots established with fixed densities of *Poa* in 1993 and 1994. (Includes plots planted with low, medium, and high densities of *Poa*.)

^b Plots cleared of all perennial grasses 1993 through 1994.

^c Biomass samples were collected from a 0.1 m² area located in the center of each 0.8 m² plot. Samples were collected in May 1994, June 1998, May 1999, May 2000, May 2001, and May 2002. Results are presented ± one standard error.

Table A5. Average density of *Poa* per 0.64 m² plot in the experimental flashing subpopulation. All averages are \pm one standard error. Numbers in parentheses indicate number of plots (*n*).

	Planted <i>Poa</i> plots			Existing <i>Poa</i> plots			Plots cleared of perennial grasses
	Low density	Medium density	High density	Low density	Medium density	High density	
1993^a							
Total	11	22	45	4	5.6	10.6	0
1999^b							
Total	2.4 \pm 0.9 (5)	3.2 \pm 0.9 (5)	9.8 \pm 4.4 (5)	1.8 \pm 0.4 (5)	1.2 \pm 0.5 (5)	1.6 \pm 1.4 (5)	0.7 \pm 0.2 (25)
Unburned	2.4 \pm 0.9 (5)	2.5 \pm 1.5 (2)	12.3 \pm 7.3 (3)	2 (1)	1.3 \pm 0.7 (3)	0.3 \pm 0.3 (3)	0.9 \pm 0.2 (15)
Burned	N/A	3.7 \pm 0 (3)	6.0 \pm 3.0 (2)	1.8 \pm 0.7 (4)	1 \pm 1 (2)	3.5 \pm 3.5 (2)	0.5 \pm 0 (10)
2000^c							
Total	4.2 \pm 0.6 (5)	8 \pm 2.5 (5)	10.6 \pm 4.1 (4)	8.6 \pm 2.7 (5)	5.1 \pm 1.8 (4)	5.6 \pm 1.6 (5)	2.4 \pm 0.9 (24)
Unburned	3.8 \pm 0.3 (4)	3.5 \pm 2.1 (2)	8.0 (1)	3.0 (1)	4.7 \pm 2.9 (3)	4.3 \pm 2.7 (3)	1.5 \pm 0.5 (13)
Burned	6.0 (1)	13.0 \pm 1.4 (2)	5 (1)	10.0 \pm 2.9 (4)	9.0 (1)	7.5 \pm 0.7 (2)	3.5 \pm 2.0 (11)
2001							
Total	4.0 \pm 0.7 (5)	5.8 \pm 0.9 (5)	8.2 \pm 1.9 (5)	5.4 \pm 0.8 (5)	3.8 \pm 1.3 (4)	4.0 \pm 1.8 (5)	2.4 \pm 0.7 (25)
Unburned	3.5 \pm 0.8 (4)	4.5 \pm 0.7 (2)	7.0 \pm 2.8 (2)	3.0 (1)	3.3 \pm 2.0 (3)	2.7 \pm 0.8 (3)	2.2 \pm 0.6 (14)
Burned	6.0 (1)	5.5 \pm 0.7 (2)	4 (1)	6.0 \pm 0.8 (4)	5.0 (1)	6.0 \pm 7.1 (2)	2.7 \pm 1.4 (11)
2002^{c,d}							
Total	4.4 \pm 0.2 (5)	6.6 \pm 0.9 (5)	12.4 \pm 1.4 (5)	4.6 \pm 0.8 (5)	3.6 \pm 1.6 (5)	5.0 \pm 1.6 (5)	2.3 \pm 0.6 (25)
Unburned	4.5 \pm 0.3 (4)	6.0 \pm 2.8 (2)	12.0 \pm 2.8 (2)	3.0 (1)	4.3 \pm 2.9 (3)	4.0 \pm 1.2 (3)	2.1 \pm 1.4 (14)
Burned	6.0 (1)	6.0 \pm 1.4 (2)	10.0 (1)	5.0 \pm 1.1 (4)	2.5 \pm 3.5 (2)	6.5 \pm 6.4 (2)	2.5 \pm 1.4 (11)

Notes:

- Planted *Poa* plots planted in fixed densities in 1993 and maintained at these densities through 1994.
 - Existing *Poa* plots created around existing *Poa* plants. No new plantings occurred in these plots.
 - Plots cleared of perennial grass were cleared only through 1994.
 - For all totals, *Poa* densities are averaged across burned, unburned, and transition plots.
 - FL Plots were last burned in summer of 1999.
 - A shift in the burn line in 1999 compared to 1998 caused some high density *Poa* planted plots to shift from the burned area to the unburned area. Two high density and one medium density *Poa* planted plots were in a transition zone between the burned and unburned area.
- ^a During this year, there was a significant ($p < 0.05$) difference in *Poa* densities between planted and existing *Poa* plots.
- ^b During this year, there was a significant ($p < 0.05$) difference in *Poa* densities in plots cleared of *Poa* compared to existing and planted *Poa* plots.
- ^c During this year, there was a significant ($p < 0.05$) difference in *Poa* densities between burned and unburned plots.
- ^d Indicates a significant interaction between starting density and plot type during the specified year.

Table A6. Average density of *Poa* per 1 m² plot in the fire frequency experimental subpopulation. All averages are \pm one standard error. There are five plots for each of the four burn frequencies. Burning began in summer 2001.

	Total all frequencies	Fire frequency ^a			
		Control	Low	Medium	High
1999 ^b	33	33	33	33	33
2000	29.3 \pm 1.4	31.6 \pm 2.2	30 \pm 1.0	29.2 \pm 0.7	26.2 \pm 5.7
2001	21.7 \pm 1.2	22 \pm 2.9	22 \pm 2.6	21.0 \pm 2.1	21.6 \pm 3.6
2002 ^c	27.2 \pm 1.8	20.6 \pm 3.2	29 \pm 1.7	31 \pm 3.6	28 \pm 5.4

^a Averages broken down by burn frequency:

Control = Unburned.

Low = Burned every fifth year.

Medium = Burned every third year.

High = Burned every other year.

^b Plots planted in 1999.

^c During 2002, the distribution was *Poa* plants was significantly different from an even distribution ($p < 0.005$).

Table A7. Final predation percentages by treatment: 1998–2002. Italics indicate significant difference ($p < 0.05$) between areas (Flashing vs. Fire Frequency vs. control area beside Fire Frequency plots) for open, unburned plots.

Year, round, and treatment	Median (%)	Mean (%)	Variance (%)	Evenness (%)	Localization (%)	<i>n</i>
1998, post-burn (Flashing only)						
Net, burned	48	51	3.2	100	20	5
Net, unburned	74	63	4.8	100	40	5
Open, burned	60	59	4.0	100	20	5
Open, unburned	79	75	0.6	100	60	5
1999, pre-burn (Flashing only)*						
Net, disturbed ^a	96	96	0.1	100	100	5
Net, unburned	96	91	1.2	100	80	5
Open, disturbed	96	91	1.2	100	100	5
Open, unburned	84	77	2.1	100	60	5
1999, post-burn (Flashing only)⁺						
Net, burned	100	97	0.1	100	100	5
Net, unburned	100	99	0.0	100	100	5
Open, burned	100	99	0.0	100	100	5
Open, unburned	96	96	0.2	100	100	5
2000, pre-trapping						
<i>Flashing</i>	14	14	0.5	80	0	5
Fire Frequency	72	49	7.9	100	40	5
Control	44	68	4.3	100	20	5
2000, post-trapping						
Flashing (no rodents caught)	33	30	0.7	100	0	5
Fire Frequency (one rodent caught)	48	24	2.9	100	20	5
Control (control)	25	47	10.6	80	0	5
2001, pre-burn						
Open, unburned (Flashing)	8	11	0.6	40	0	5
Open, unburned (Fire Frequency)	8	11	1.2	40	0	5
2001, post-burn Fire Frequency only						
Net, burned	50	37	10.3	67	0	3
Open, burned**	84	87	1.2	100	75	8
Open, unburned	61	47	7.6	100	0	5
2002 pre-burn						
Open, unburned (Flashing)	20	21	0.02	80	0	5
Open, unburned (Fire Frequency)	29	45	0.2	80	30	10
2002 post-burn						
<i>Open, unburned (Flashing)</i>	20	21	0.01	100	0	5
Open, unburned (Fire Frequency)	56	58	0.09	100	60	10
Open, burned (Fire Frequency)**	100	100	0	100	100	5

n = Number of plots.

^a Burned previous year.

^{+,*} Different symbols indicate rounds significantly different within year, $p < 0.01$.

** Treatment significantly different ($p < 0.05$) from other treatments within trial.

Table A8. Final predation intensities: all rounds, sites, treatment and cover types combined: 1995–2002.

Year ^a	Median (%)	Mean (%)	Variance (%)	Evenness ^b (%)	Localization ^c (%)	n
1995 ⁺	37.5	42.6	14.5	69	24	42
1998 ^{*,d}	79.6	70.7	5.4	100	56	50
1999 [#]	96	93	1.0	100	93	40
2000 ⁺	32.7	38.8	7.1	93	13	30
2001 ⁺	37.0	44.1	12.9	73	23	26
2002 ⁺	34.0	46.6	6.8	90	27	30

Notes:

n = Replicate number.

^a Years with different symbols (+, *, #) indicate that the medians are significantly different ($p < 0.0015$).

^b Evenness is the percent of plots missing at least one nutlet by the end of the round.

^c Localization is the percent of plots with less than 5 nutlets remaining at the end of the round.

^d Ant-only treatment excluded.

Section B
Blepharizonia plumosa
Monitoring and Research

Section B

Blepharizonia plumosa Monitoring and Research

B-1. Introduction

Several populations of *Blepharizonia plumosa* (the big tar plant, known also as *Blepharizonia plumosa* subsp. *plumosa*) were identified during a habitat survey in 1996 at Site 300 (Preston, 1996; 2002). Listed as *Blepharizonia plumosa* subsp. *plumosa* by the California Native Plant Society (CNPS), it is an extremely rare late-season flowering annual plant included on the CNPS List 1B (Tibor, 2001). The CNPS List 1B includes plants that are rare, threatened, or endangered. The CNPS R-E-D code (rarity-endangerment-distribution) for *B. plumosa* is 3-3-3, indicating that this plant is limited to one population or several restricted ones, is endangered throughout its range, and is endemic to California. The CNPS also noted that possibly the only remaining populations exist on private property in the hills near Livermore, California. Populations have been previously identified in Alameda, Contra Costa, San Joaquin, Stanislaus, and Solano Counties (Skinner and Pavlik, 1994). Preston (1996) noted that a population was discovered at Contra Loma Regional Park, south of Antioch in 1979, but that surveys conducted by the East Bay Regional Park District in 1991 were unable to relocate the subspecies. In 1994, several more populations were discovered on private property southwest of Brentwood (CNDDDB, 1996). Another small population was found at Chaparral Springs, near Mount Diablo (Preston, 1996). Current status of these populations is unknown. Also during the 1996 and 2002 habitat surveys of Site 300, a few populations of the more common big tarplant, *Blepharizonia laxa* (also known as *Blepharizonia plumosa* subsp. *viscida*), were also found. Neither species has been extensively studied, particularly *B. plumosa* subsp. *plumosa*.

The genus *Blepharizonia* has recently been taxonomically revised. Baldwin et al. (2001) found that what had been considered two similar plant subspecies are truly two co-occurring, separate species. *Blepharizonia plumosa* subsp. *plumosa* retained the specific moniker *B. plumosa*, and *B. plumosa* subsp. *viscida* is now known as *B. laxa*. The most current nomenclature for these species will be used throughout this report. Both *B. plumosa* and *B. laxa* are dicots within the family Asteraceae (the sunflower family), and members of the tribe Helenieae (Karis and Ryding, 1994). They are both summer annual forbs, which germinate with the onset of the first substantial fall/winter rains and flower July through October. The plants are heterocarpic, producing dimorphic flowers within the same inflorescence. Disc seeds are produced from the central or disc flowers of the inflorescence and ray seeds are produced from the peripheral ray flowers. The disc flowers are whitish in color while the ray flowers are white with purple vein and deeply three lobed (Bremer, 1994).

Blepharizonia plumosa can generally be distinguished from *B. laxa* by fruit morphology and leaf color (Hickman, 1993; personal observation). The most distinctive characteristic of *B. plumosa* is the pappus of 1.5 to 3mm in length on the disc fruits. This pappus, sometimes described as

plumose (thus the name *plumosa*), contrasts with the very minute pappus of the ray fruits (Figure B1). The plants also have a pale green color as their foliage is sparsely glandular below the inflorescence. Older plants have many inflorescences on lateral side branches.

Blepharizonia laxa, although also endemic to California, exists in large numbers and has a much larger range which extends farther south into the inner South Coast Ranges including San Benito County (Hickman, 1993). The disc and ray seeds of *B. laxa* appear quite similar and have a short pappus from 0–1 mm in length (Figure B1). *Blepharizonia laxa* is much more glandular than *B. plumosa*, giving the plant a more yellow-green color and a much stronger scent. They also tend to be slightly taller than *B. plumosa* (personal observation). Older plants have inflorescences mostly terminal on slender wand-like, bracted peduncles (Hickman, 1993).

Many areas at Site 300 are annually burned in the late spring/ early summer as a means of wildfire control (Figure B2). Although rare outside of Site 300, *B. plumosa* is quite common at Site 300, occurring in large numbers in areas that are routinely burned. This is interesting, for at the time of the annual spring burns at Site 300, the plant is in a green vegetative stage, and thus very susceptible to fire damage. It is possible that the larger Site 300 *B. plumosa* population may be acting as a metapopulation. Smaller subpopulations may be established or extinguished, depending on fire uniformity and intensity. And although fire is potentially fatal to individual *B. plumosa* plants directly in its path, it may provide the amount of disturbance necessary to reduce competition and allow for subpopulation establishment, thus maintaining the metapopulation.

And while common throughout its range, *B. laxa* is very uncommon at Site 300. *Blepharizonia laxa* populations occur sporadically in both unburned and burned areas. The two species occur sympatrically (together) in only a few locations. That the two species appear to differ in their habitat requirements may indicate some ecological differentiation between them.

For conservation and management purposes, a thorough understanding of the population dynamics of *B. plumosa* is necessary. *Blepharizonia laxa* is also of interest as comparisons of rare and common congeners can provide important information for rare plant management (Bevill and Louda, 1999; Pantone et al., 1995) and can illuminate differences that affect comparative abundance (Byers, 1998). Therefore, in November of 1996, we began collecting basic demographic and population biology data on *B. plumosa*. Because so little is known about population biology of this species, and because ongoing activities at Site 300 could potentially impact the populations, these data will be useful for both improving management practices and in preparing for any necessary onsite mitigation. Little information also exists in the literature on *B. laxa*, therefore we began collecting limited information on this species as well. In 1996, three populations of *B. plumosa* (designated B834 Berm, Elk Ravine [or B834 Drainage], and B850), and one population of *B. laxa* (designated Middle Canyon), were delineated for monitoring purposes. B834 Berm has not been monitored since 2000, but B812, where *B. plumosa* and *B. laxa* have co-occurred, was selected as an additional monitoring location in 2001. Figure B3 shows the location of the four populations currently monitored and Table B1 describes some of their habitat characteristics.

We have begun to discern ecological differences between *B. plumosa* and *B. laxa* (Gregory et al., 2001), however we cannot yet explain the relative differences in abundance between the two species at Site 300. Therefore, current and future work focus on understanding the population dynamics of *B. plumosa* across the entire site. If indeed *B. plumosa* is acting as a large metapopulation, smaller subpopulations may be of less importance. But we must verify that *B. plumosa* is indeed acting as a metapopulation, and understand how it is maintained before we can

be certain loss of smaller subpopulations will not threaten the overall metapopulation. And by continued work with *B. laxa* we will gain a better understanding of the mechanisms controlling the relative abundance of the two species at Site 300.

B-2. Methods and Materials

B-2.1. Monitored populations

In the late spring of 2002 prior to the annual burn, randomly selected plants in each population were marked. A point-compass method was used to select plants for marking. A two foot square piece of cardboard with a large compass drawn on its face was placed at each of between three and eight locations, the number and placement of which was determined by the size of the population to ensure no large groups of plants were outside the selection range. A survey pin was passed through the end of a meter tape and used to anchor the center of the cardboard compass to the ground. Randomly generated numbers set the degree angle and the number of meters away from the center point of the compass that determined the location of each sample point. The *B. plumosa* or *B. laxa* plant closest to the sample point was marked.

One hundred plants were marked at the B812, B850 and Elk Ravine populations, and 65 plants at Middle Canyon were marked. At Middle Canyon, the point-compass method was not used, but all plants that could be located were marked. Plant heights and species of nearest neighbors were also collected at this time. After the burn, the plant markers were censused for surviving plants. Middle Canyon, which was unburned, was also censused at this time. The height of any plant surviving was recorded, and the marker was removed if the plant was missing or dead. The microtopography of all marked plants was noted as either exposed or sheltered. The area around the plant was characterized as burned or unburned. Because of the high degree of mortality observed at the Elk Ravine and B850 populations as a result of the burn, additional plants were marked for monitoring to flowering. In the Elk Ravine population, only one plant was located within the burned area, nine plants were located along Linac Road, nine were located along the fire trail that was not burned off of Linac Road, and three plants were located along the fire trail in Elk Ravine. At B850, four live plants were located along the fire trail and two within the burned area. All marked plants were censused once again at the time of flowering and height data were collected for all plants found.

For the flowering census in fall of 2001, all plants, marked or unmarked, were measured at flowering on 13–14 Sept 01. In late spring of 2002, the pre-burn sampling of Elk Ravine and B812 was conducted on 23 May 02, the pre-burn sampling at B850 and Middle Canyon was conducted on 30 May 02. Markers were censused post-burn on 11 Jun 02 and 01 Jul 02 (Elk Ravine), 01 Jul 02 (B812), 20 Jun 02 and 03 Jul 02 (B850), and 03 Jul 02 (Middle Canyon). For the flowering census for fall of 2002, only marked plants were measured. Fall flowering census was conducted on 13 Sep 02 (Elk Ravine, B850, and Middle Canyon) and 17 Sep 02 (B812).

B-2.1.1. Data Analysis

For species diversity index calculations (pre-burn nearest neighbor data collected 1999–2002), Shannon's index (Shannon and Weaver, 1949) was used: $-\sum_{i=1}^S (n_i/n) * \ln(n_i/n)$, where

S is the number of species observed; n is the number of individuals observed; and n_i is the number of individuals in the i th species.

B-2.2. Site-wide Mapping

On 27 Sep 96, 4 Oct 96, and 23 Sep 97 Robert Preston surveyed the entire site for flowering *B. plumosa* populations and visually estimated population locations and sizes, hand-mapping them on a large-format map (Preston, 2002)

On 22 Oct 99 and 29 Oct 99 and on seven dates between 20 Oct 00 and 8 Nov 00, all areas of Site 300 were surveyed for flowering *B. plumosa* populations. All *B. plumosa* and *B. laxa* populations found were mapped using a Trimble GPS unit.

On three dates between 25 Oct 01 and 08 Nov 01, the northern and western areas of Site 300 were surveyed for flowering *Blepharizonia* populations. The remainder of the site was not surveyed due to manpower limitations. All *B. plumosa* and *B. laxa* populations found were mapped using a Trimble GPS unit. The number of individuals were either counted or visually estimated for each population mapped.

On seven dates between 25 Sep 02 and 30 Oct 02, all areas of Site 300 were surveyed for flowering *Blepharizonia* populations. All *B. plumosa* and *B. laxa* populations found were manually mapped using a large-scale topographic map (1 in.: 600 ft). The number of individuals were either counted or visually estimated for each population mapped.

B-3. Results

B-3.1. Monitored Populations

Post-burn survivorship of *Blepharizonia* is generally low (Table B2). When comparing survivorship in burned areas to unburned areas, the effect is unmistakable. Nearly all the plants that survive the burn are in areas that escape the flames. Although each population is “burned”, burns can be patchy and some areas within the population remain untouched. Burned areas generally have no *Blepharizonia* survivorship. The burns at both Elk Ravine and B850 have been mostly “complete” (i.e., leaving few patches of unburned area), especially in recent years. This may be due to the general trend towards conducting burns later in year (Table B3) when conditions are drier and hotter. Interestingly, the burn at B812 has been consistently patchy, leaving several unburned areas containing surviving *B. laxa* plants.

Plants that survive the burn have reasonably good survivorship to flowering, although this is highly variable between years and between populations. Plants in Elk Ravine showed a very high survivorship to flowering in 2002, while survivorship in the other populations ranged between 24 and 44% (Table B2). However, the Elk Ravine survivorship estimate may be biased upward, as these plants were marked after the burn in areas adjacent or outside the immediate burn area. These plants were quite large at the time of marking. No plants could be found in the burn area after the burn. The large amount variability within our results may be due to differences in sample size and to methodology.

Species composition of nearest neighbors continued to exhibit differences between populations. *Erodium cicutarium*, *Vulpia myuros* and *Poa secunda* comprise the bulk of the nearest neighbors

at B850 and Elk Ravine (Figures B4 through B7). However, significant amounts of *B. madritensis* subsp. *rubens* is observed at Elk Ravine whereas *B. hordeaceous* is observed at B850. Middle Canyon is dominated by *B. diandrus* and *Avena*, with some *B. madritensis* subsp. *rubens* and *B. hordeaceous* (Figure B8). B812 nearest neighbor composition has characteristics of B850, Elk Ravine and Middle Canyon, with both *B. hordeaceous* and *B. madritensis* subsp. *rubens* observed, a much larger amount of *E. cicutarium*, a lesser density of *P. secunda*, and a significant quantity of *Avena* (Figure B9).

Species diversity values appear relatively consistent within populations from 1999 through 2002 (Table B4). Values at Elk Ravine range from 1.64 to 1.99 and values at B850 range from 1.61 to 2.05. Species diversity values at B812 were also generally in the range of those observed for Elk Ravine and B850 (1.64 to 1.99), whereas values observed at Middle Canyon were somewhat lower (1.24 to 1.67). Estimates from 1997 may be higher than successive ones due to the difference in measurement technique. Nearest neighbor measurements tend to focus on small, understory plants to the exclusion of overstory plants, and cover estimates allow for more equal treatment between understory and overstory plants.

Figure B10 shows the average heights of plants at the pre-burn, post-burn and flowering census. When the average plant height is shorter post-burn, this indicates a larger death rate among taller plants. This occurred at Elk Ravine in both 1999 and 2000 and at B850 in 1999. When average plant height is taller after the burn than before it, the results are more difficult to interpret. When the pre-burn census occurs close to the burn, we can accurately assess if burning differentially affects short plant versus tall plant survivorship. When there is time for plant growth after the burn and before the census, we cannot say what the cause of increase is for average height. In 2002, burns were conducted 11 and 20 days after the pre-burn census at Elk Ravine and B850, respectively. The results suggest the larger plants were better able to survive the burn in 2002. By contrast, in 2001, burns were conducted 55 and 61 days after the first census. Burn times are becoming more difficult to predict, due to the increasing number of constraints upon the fire department in conducting the burns. Hence, burns in 2001 occurred over a longer time span and were anywhere from 24 to 53 days after the first (pre-burn) census. The longer a period of time occurs between the pre-burn census and the burns, the less accurately the height data collected represent the heights of the plants undergoing the burn. In addition, it appears that the plants available to measure after the burn have survived the burn more due to burn patchiness than due to their size.

In general, plants are taller at flowering than at the post-burn census (Figure B10). While this result is to be expected, it is not universal. Plants at B850 in 2000 were tallest at the post-burn census, indicating that taller plants died at disproportionate rates prior to flowering. There are no obvious differences in plant height between *B. plumosa* and *B. laxa*.

B-3.2. Site-wide Mapping

Figures B11 and B12 show the results of *Blepharizonia* mapping and/or burning conducted between 1996 and 2002 and reveal that *Blepharizonia* population size is reduced due to direct impacts of burning, and that populations re-emerge during years of limited burning. For example, comparing the northeast corner of the site in Figure B12c and B12d, small populations in burned areas in 2001 are transformed into large populations in the same area not burned in 2002. This relationship is shown in greater detail in the map enlargements that follow the summary maps

(Figures B13 through B19). Over the time period 1996–2002, the trend has been towards conducting the burns later in the year (Table B3). This results in a greater burn intensity due to drier conditions and higher temperatures. As results of the population monitoring show, *Blepharizonia* does not survive being burned directly, but rather persist in patches that are not directly exposed to the flames. The site-wide mapping shows that in the first or second year after a burn, if that area is not burned again, large *B. plumosa* populations can re-establish.

B-4. Recommendations and Future Work

By mapping *B. plumosa* populations on a yearly basis, we are gaining a better understanding of the mechanisms at work controlling the distribution of this species. *Blepharizonia plumosa* is so widespread at Site 300 that mapping over multiple years is required to provide information on the relationship between population presence and burn frequency. Intensity and timing of burn may be confounding factors and, in absence of the ability to control these effects, several years of data are needed to shed light on the relationship between *B. plumosa* and the annual burns that occur at the site. The information gained from monitoring the burn survivorship at B850, Elk Ravine and B812 was useful in interpreting the site-wide data. As we have shown reasonably conclusively that *B. plumosa* does not survive direct contact with the flames, but rather in patches of unburned habitat, we will discontinue collecting these data. However, it is now important to determine if seedling recruitment is enhanced in burned vs. unburned areas. That is, while burning may cause direct mortality of plants in the year of the burn, it may enhance seedling recruitment (through the presumed reduction in plant competition) the following year if the area is not again burned. Mapping results from the northeastern portion of the site suggests this to be the case. As such, we would expect to see a decline in this population over time if the area is not periodically burned. Next year we plan to begin collecting seedling recruitment data in burned versus unburned patches. This, along with the yearly site-wide mapping, should help us to predict the frequency of burning required to maintain *B. plumosa* populations. Middle Canyon will continue to be tracked in order to compare ecological requirements between *B. plumosa* and *B. laxa*.

A large seed germination experiment could also be undertaken to determine the effect of fire exposure on ray seed germination. Including *B. laxa* seeds would further elucidate some of the mechanisms of co-occurrence between the two species.

Another outstanding question with respect to the Site 300 *B. plumosa* population is that of gene flow. The Site 300 *B. plumosa* population may be acting in one of three ways: (1) a true metapopulation, in that gene flow is semi-restricted, with most of the gene flow occurring within subpopulations, with limited gene flow occurring between subpopulations, (2) one large population, with extensive gene flow occurring between all subpopulations, the locations of the subpopulations being environmentally controlled (i.e., a pseudo-metapopulation), or (3) many small populations, with no gene flow among them. We have been operating under the hypothesis that the Site 300 *B. plumosa* population is either 1 (a true metapopulation) or 2 (a single large population with pseudo-metapopulation dynamics). Under either case, the loss of a subpopulation would not particularly impact the larger Site 300 population, assuming it is within some undetermined threshold. However, should 3 (individual populations) be the case, a much different management scheme may be necessary. In this case, each population is valuable from an evolutionary perspective and theoretically should be protected. The best method to determine the population

structure at this level is through molecular and/or genetic analysis of plants from subpopulations across the site. Should funding opportunities arise, this work should be considered.

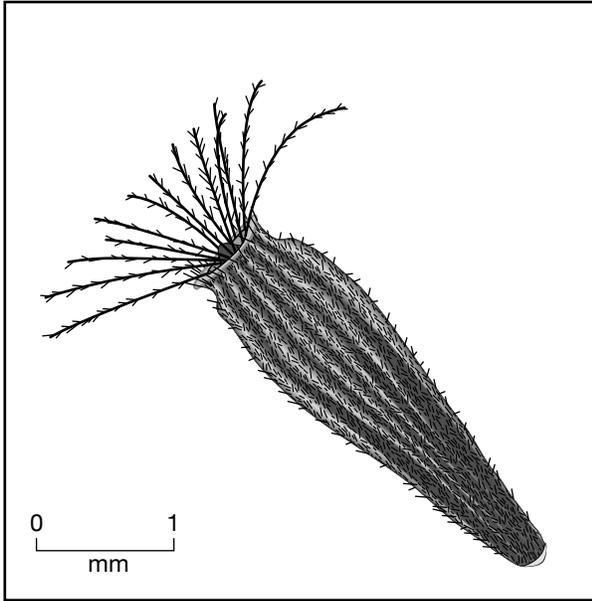
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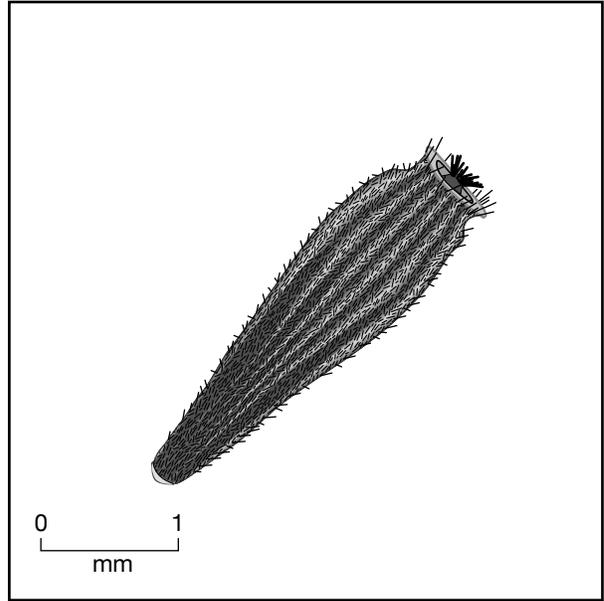
Section B
Figures

Rare Tarplant, *Blepharizonia plumosa*

Disc

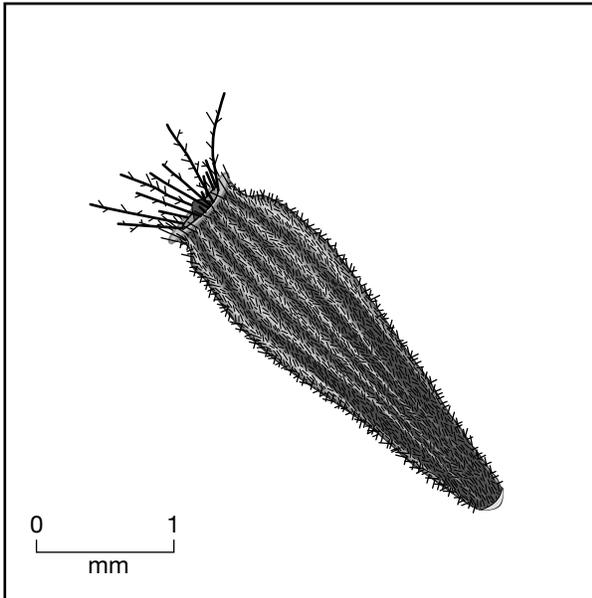


Ray

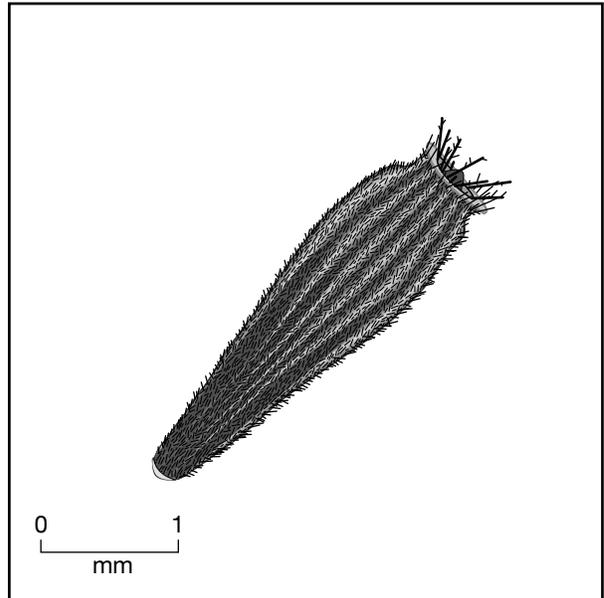


Common Tarplant, *Blepharizonia laxa*

Disc

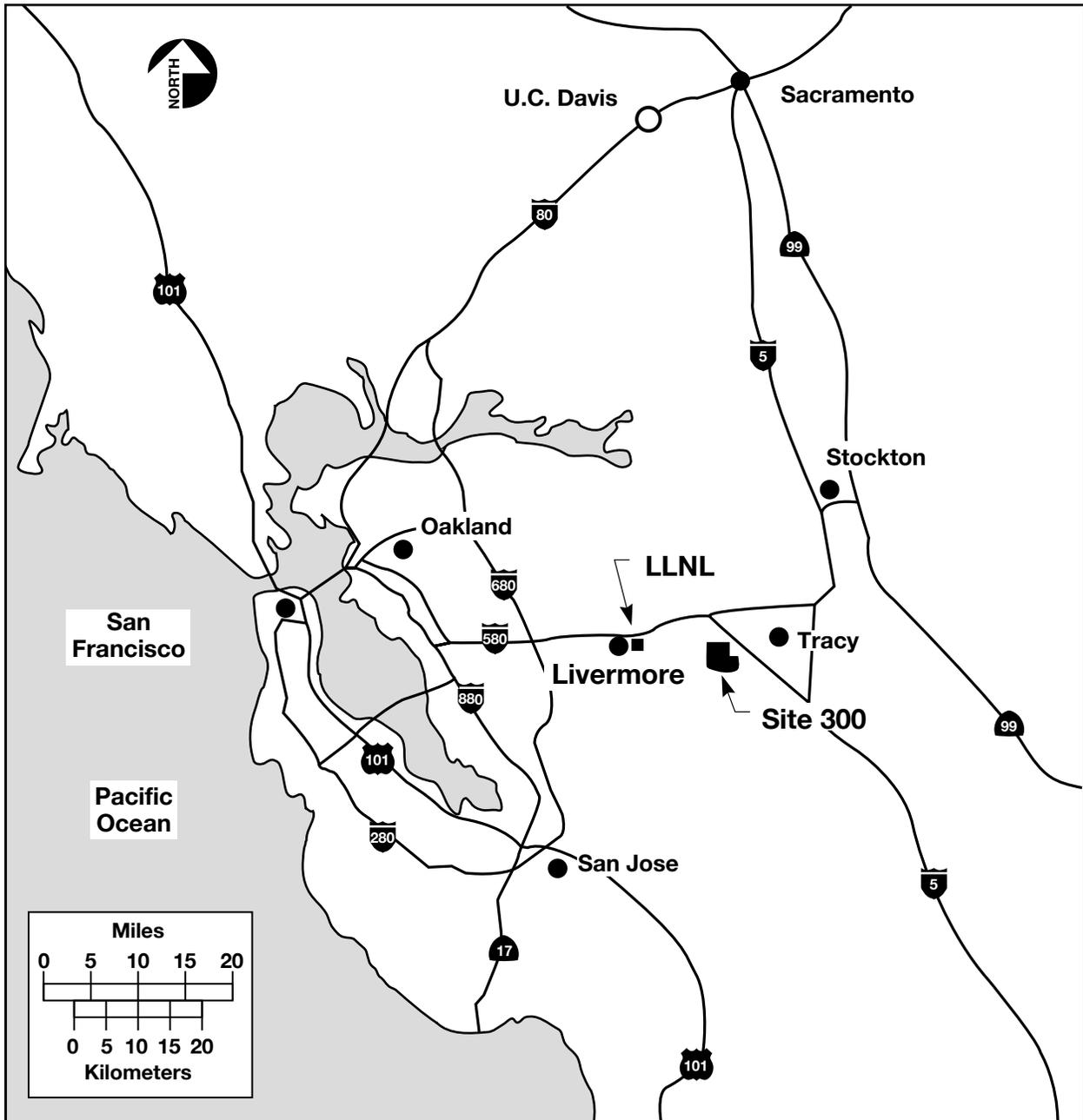


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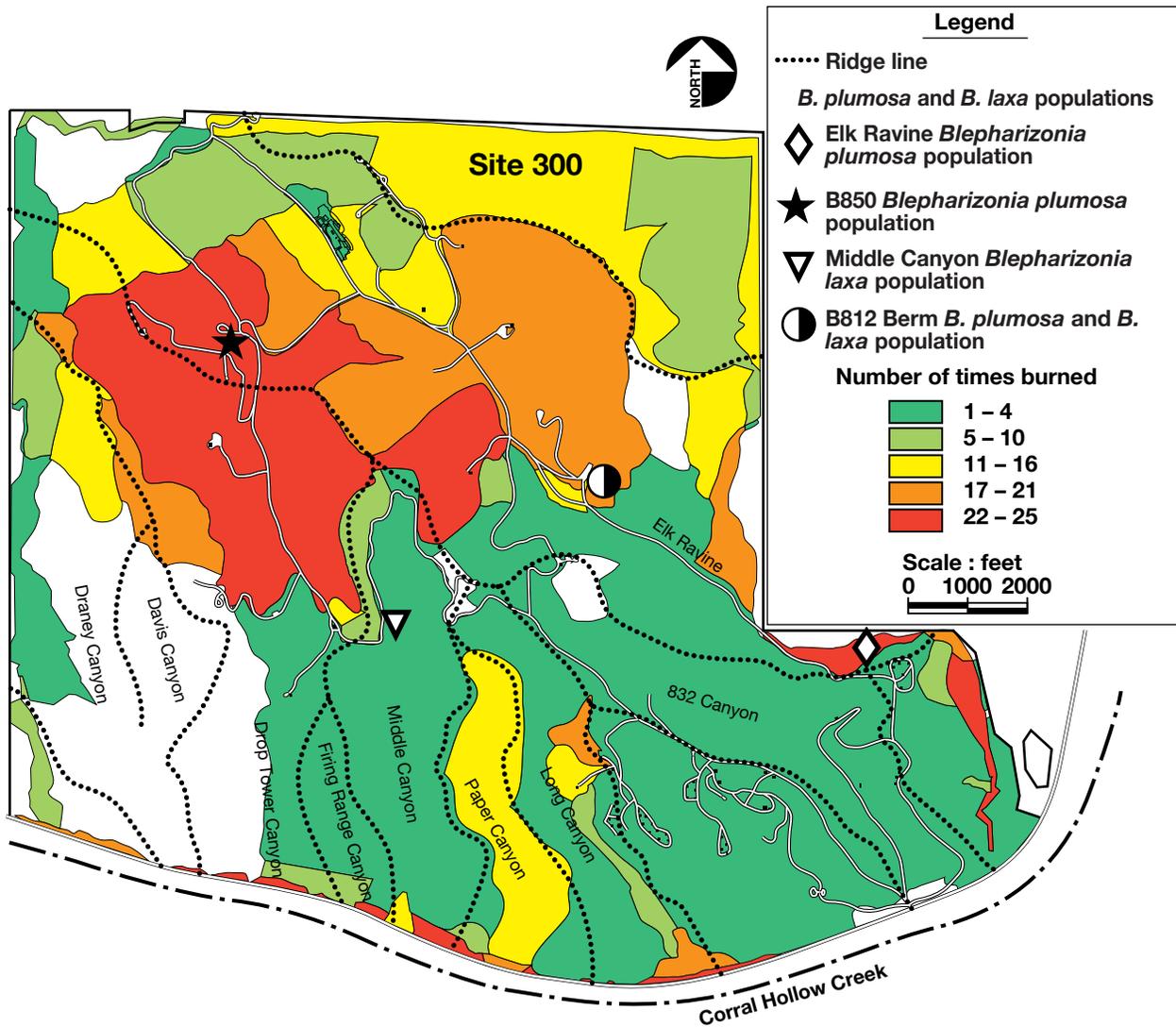
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Figure B1. *B. plumosa* fruit and *B. laxa* fruit.



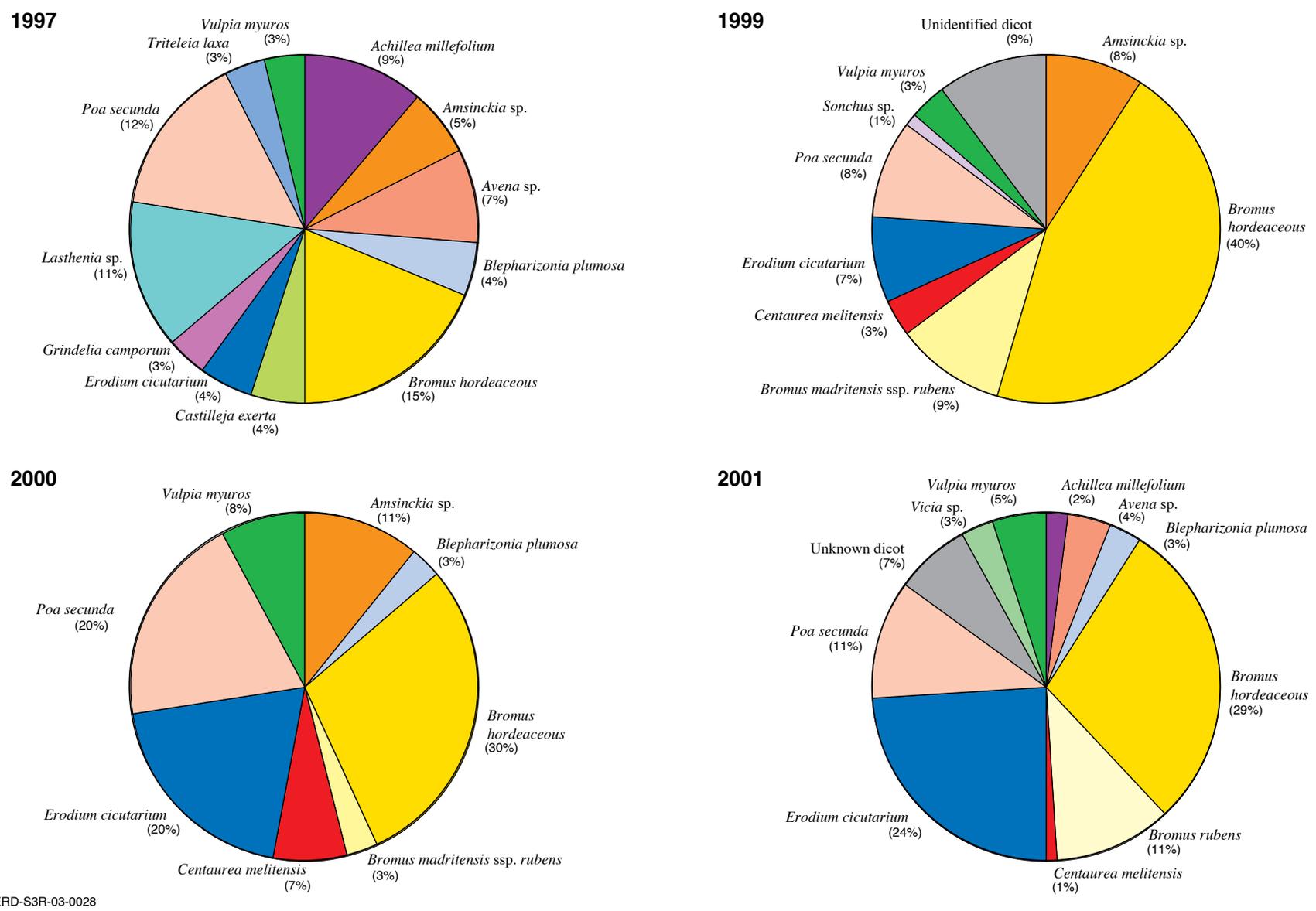
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Figure B2. Location of Lawrence Livermore National Laboratory (LLNL) Site 300.



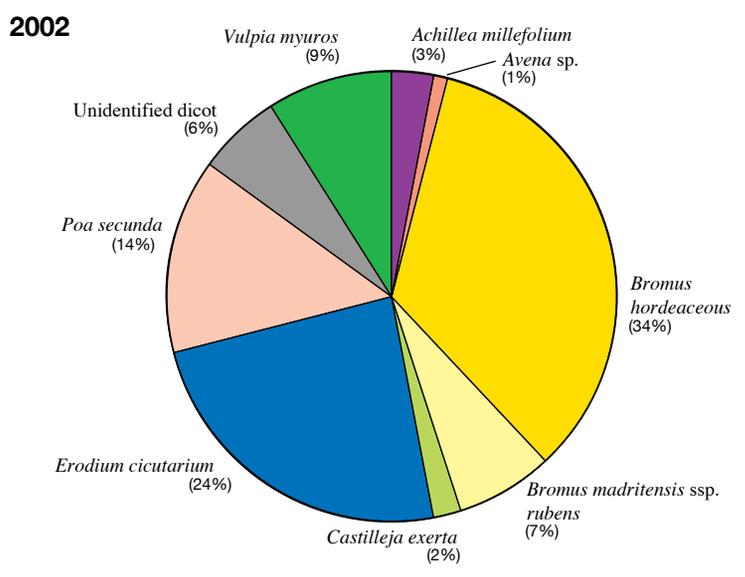
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Figure B3. Location of *Blepharizonia plumosa* and *Blepharizonia laxa* populations currently monitored at LLNL Site 300 with twenty-five year fire frequency.



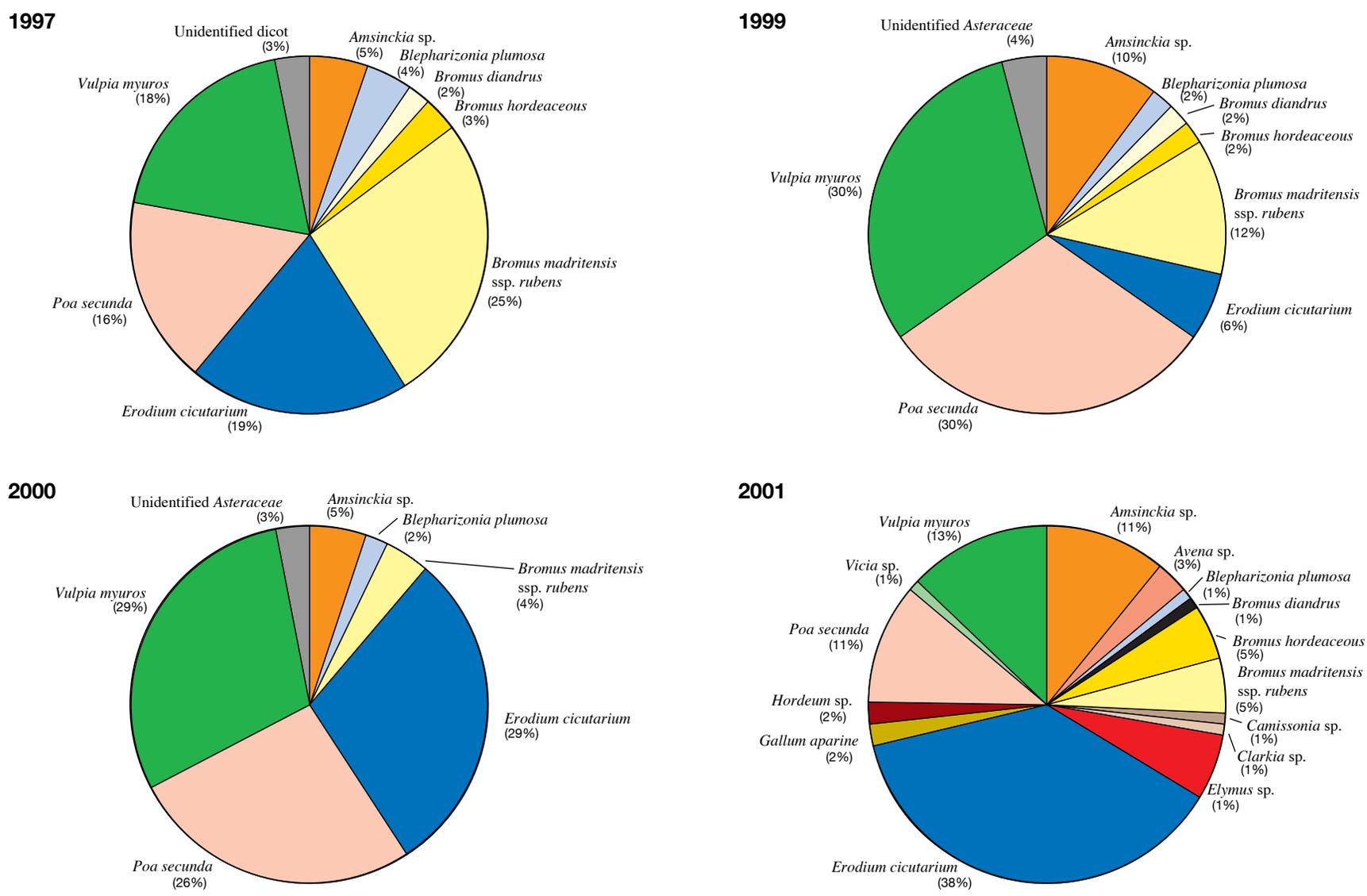
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Figure B4. Species composition of *Blepharizonia plumosa* nearest neighbors at Building 850: 1997 and 1999–2001. 1997 data are percent cover estimates normalized for comparison.



ERD-S3R-03-0029

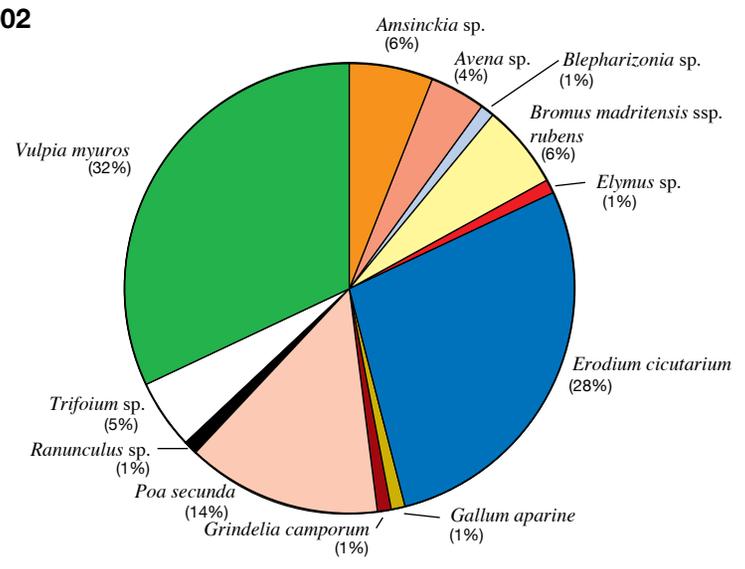
Figure B5. Species composition of *Blepharizonia plumosa* nearest neighbors at Building 850 in 2002.



ERD-S3R-03-0030

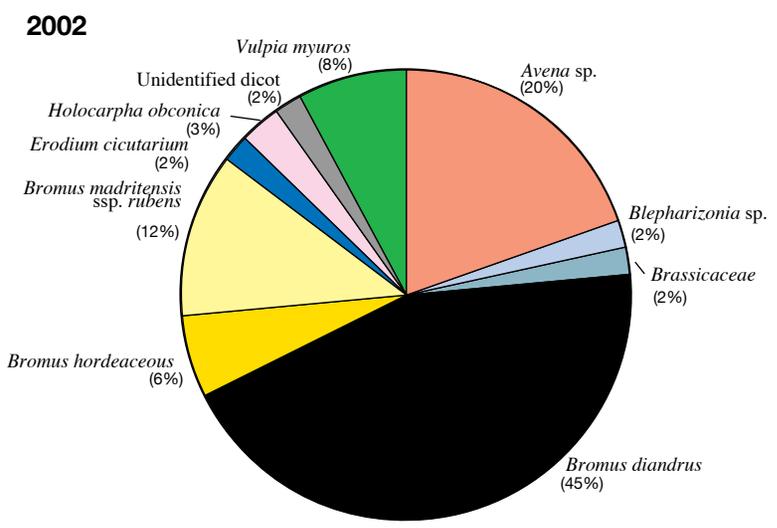
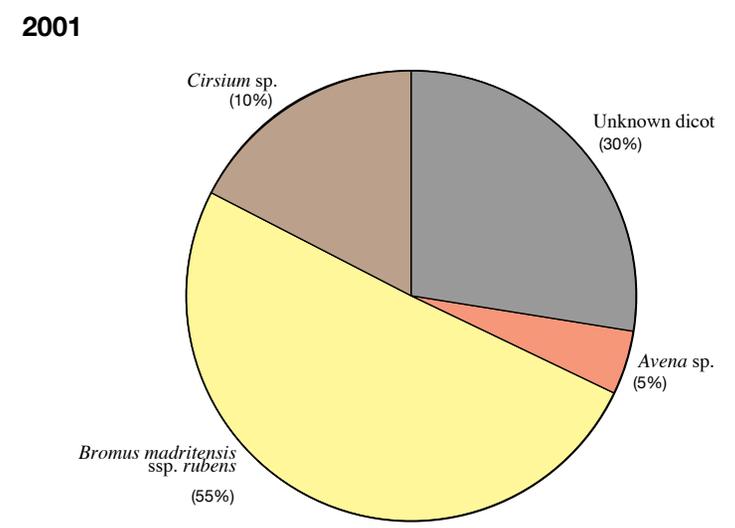
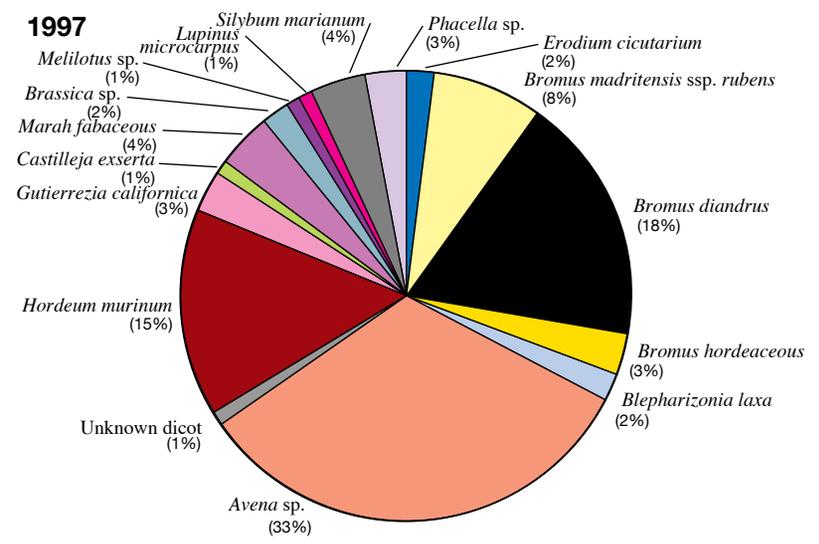
Figure B6. Species composition of *Blepharizonia plumosa* nearest neighbors at Elk Ravine: 1997 and 1999–2001. 1997 data are percent cover estimates normalized for comparison.

2002



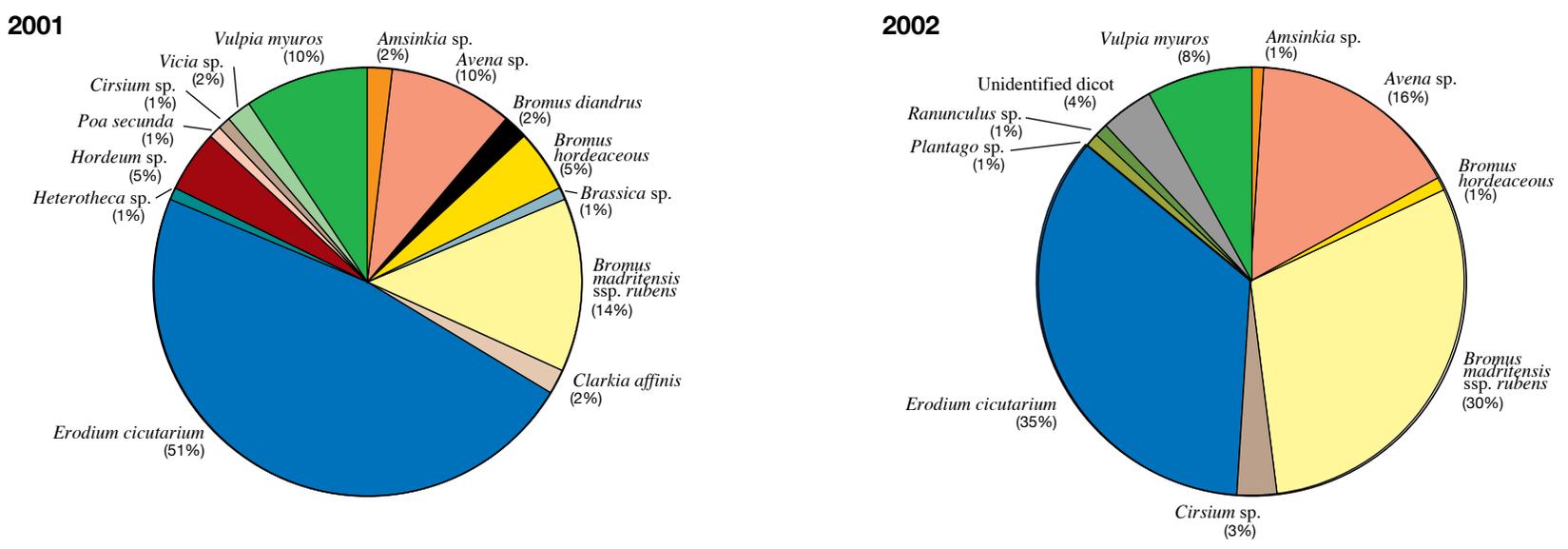
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Figure B7. Species composition of *Blepharizonia plumosa* nearest neighbors at Elk Ravine in 2002.



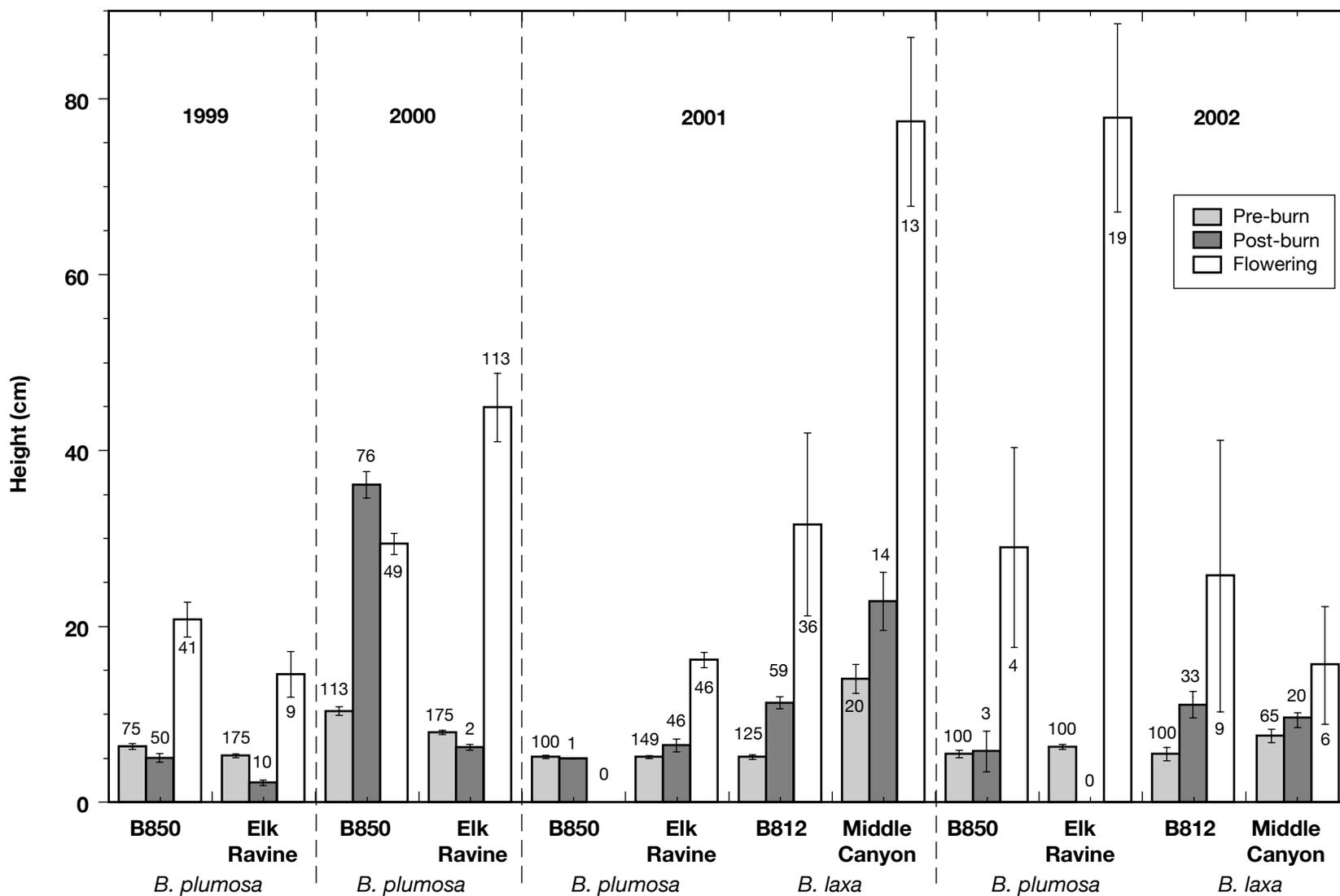
ERD-S3R-03-0032

Figure B8. Species composition of *Blepharizonia laxa* nearest neighbors at Middle Canyon: 1997 and 2001–2002. 1997 data are percent cover estimates normalized for comparison.



ERD-S3R-03-0033

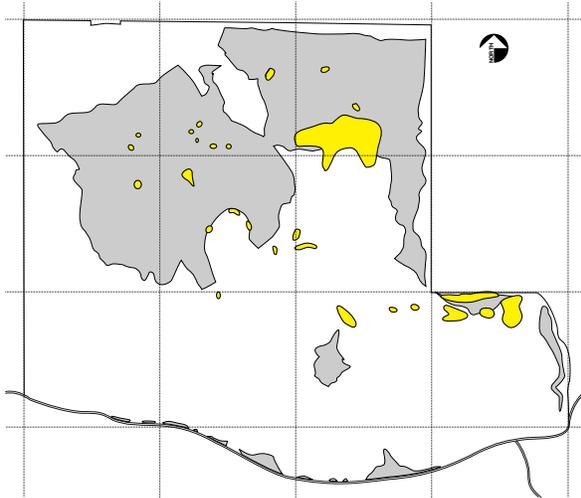
Figure B9. Species composition of *Blepharizonia laxa* nearest neighbors at Building 812: 2001–2002.



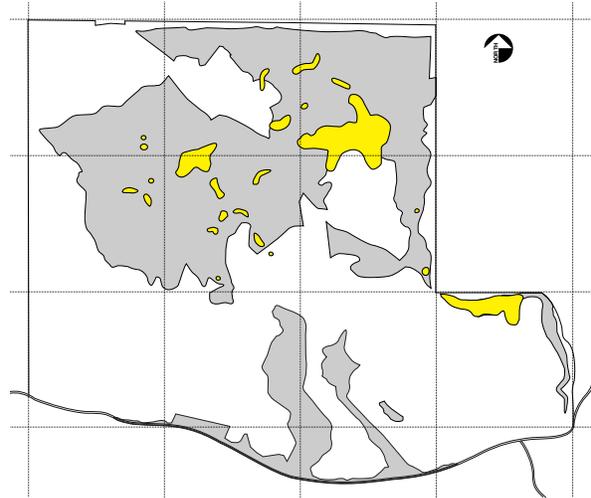
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Figure B10. Mean height of *Blepharizonia plumosa* and *Blepharizonia laxa* pre-burn census, post-burn census and flowering census: 1999–2002. Numbers in columns are n. Bars are one standard error.

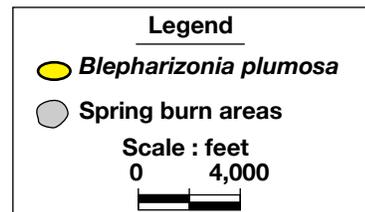
a) 1996



b) 1997



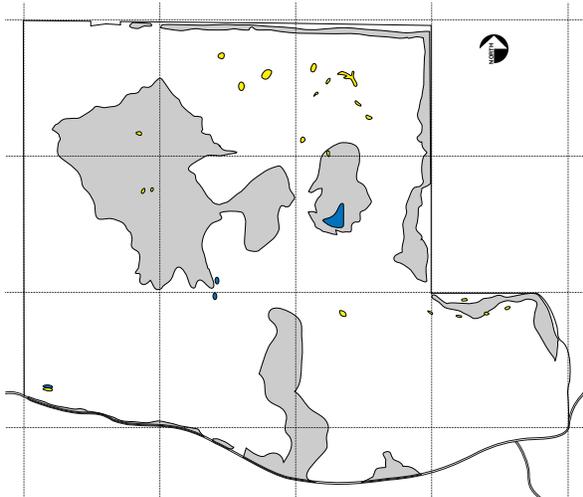
c) 1998



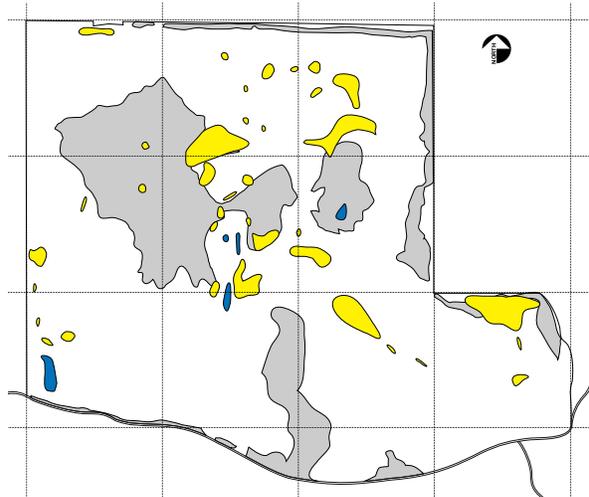
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Figure B11. *Blepharizonia* populations mapped in the fall of 1996–1997. Areas burned in each Spring (1996–1998) are shown, a) 1999, b) 1997, c) 1998 burned areas. For map enlargements, refer to Figures B16 through B19.

a) 1999



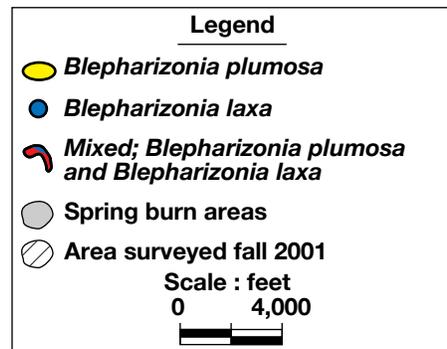
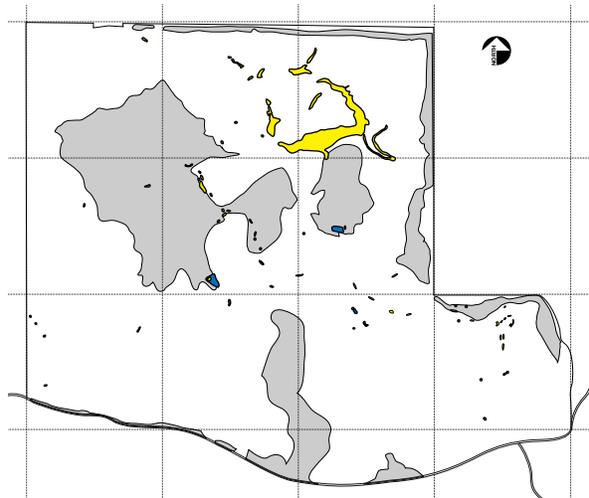
b) 2000



c) 2001

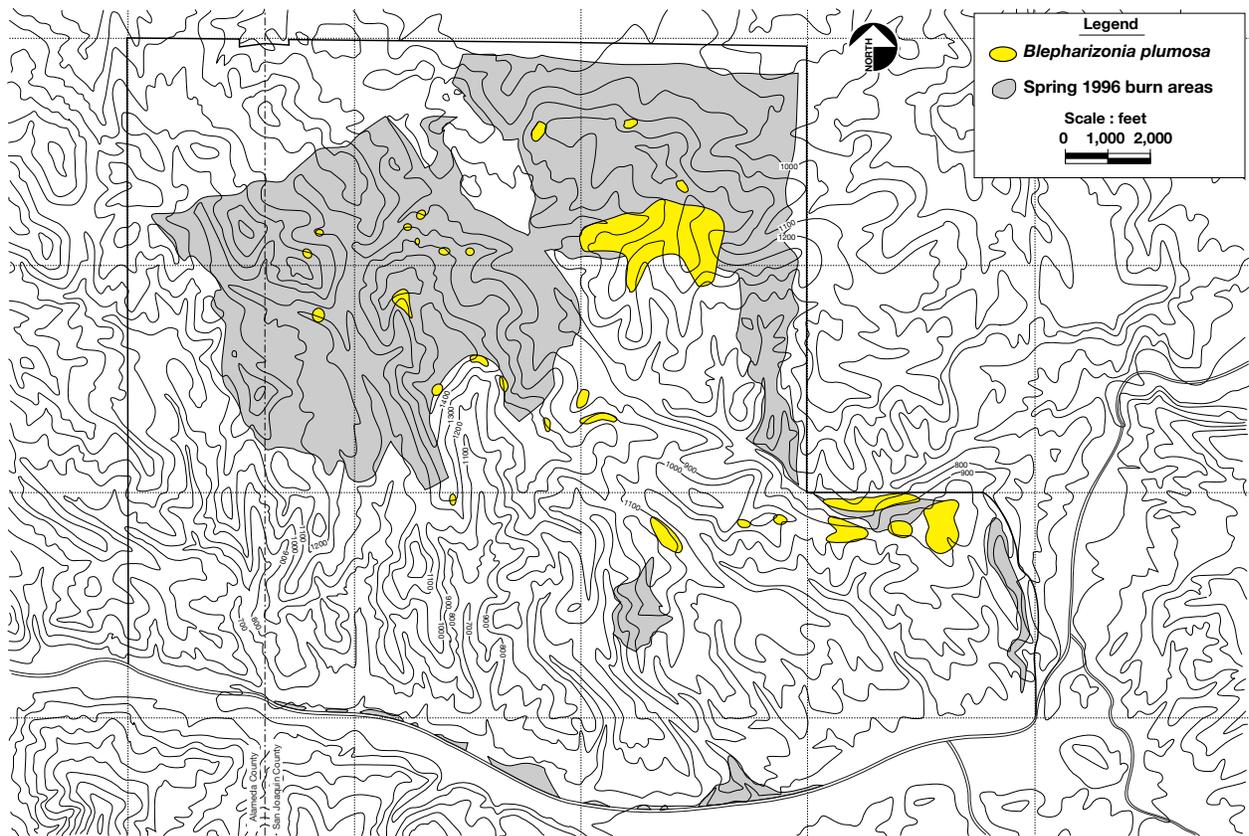


d) 2002



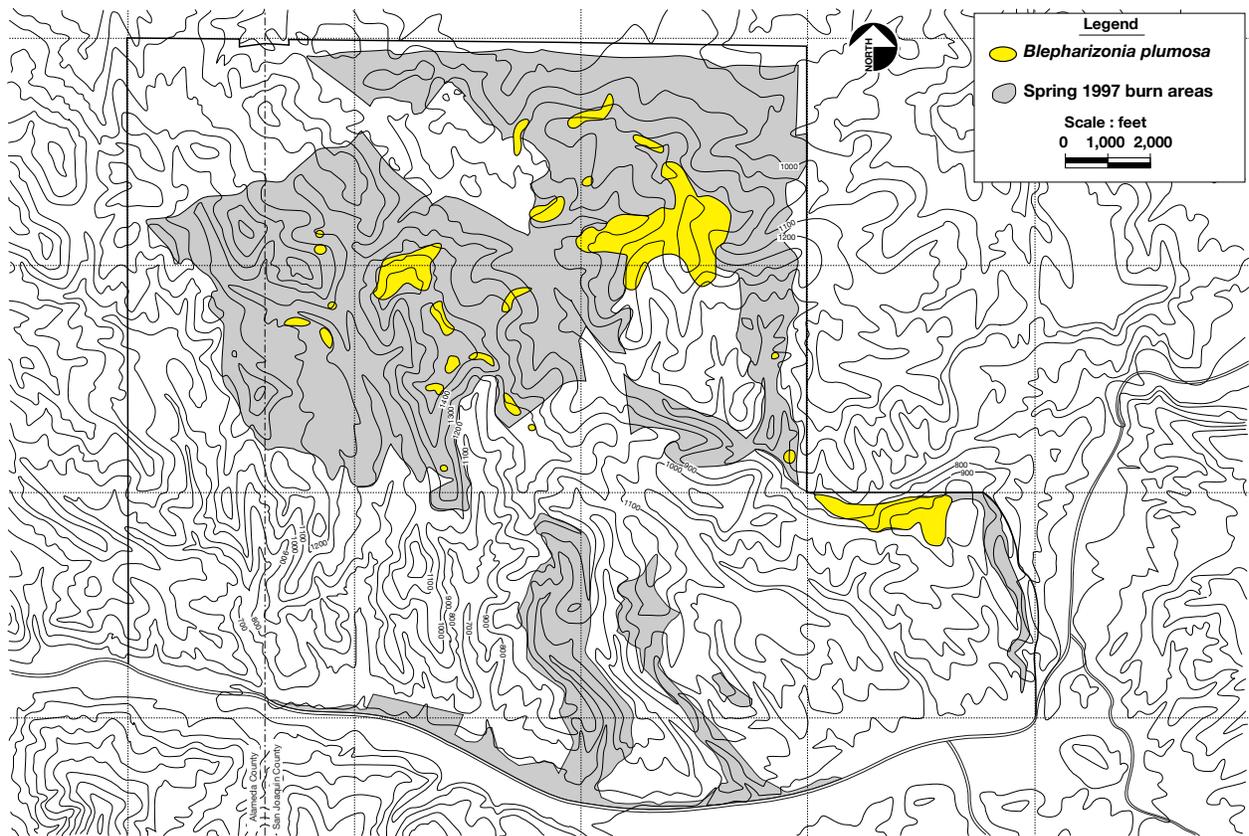
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Figure B12. *Blepharizonia* populations mapped in the fall of 1999–2002. Areas burned in each Spring shown, 1)1999, b) 2000, c) 2001, d) 2002. For map enlargements, refer to Figures B16 through B19.



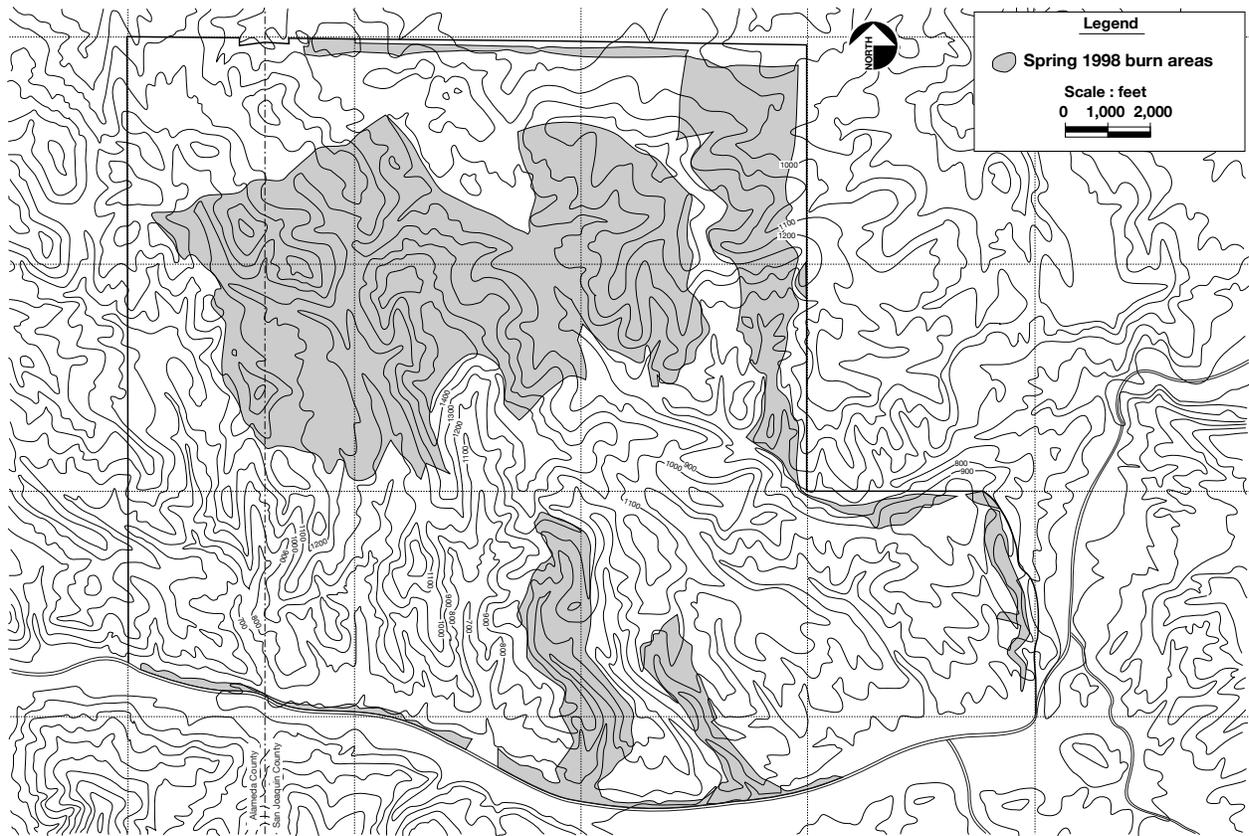
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Figure B13. Enlargement of Figure B11a. *Blepharizonia* mapped in the fall of 1996 by R. Preston (Preston, 2002). Areas burned in spring of 1996 shown.



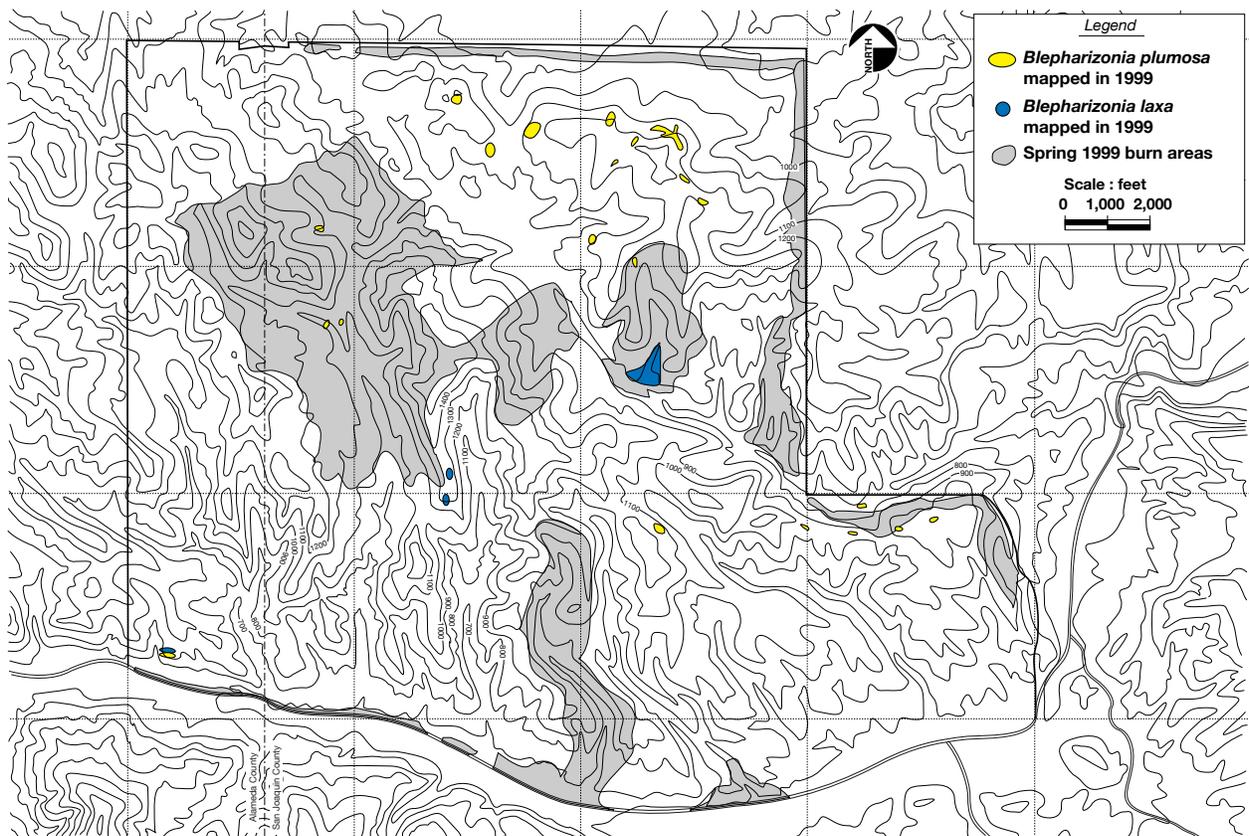
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Figure B14. Enlargement of Figure B11b. *Blepharizonia* populations mapped in the fall of 1997 by R. Preston (Preston, 2002). Areas burned in spring of 1997 shown.



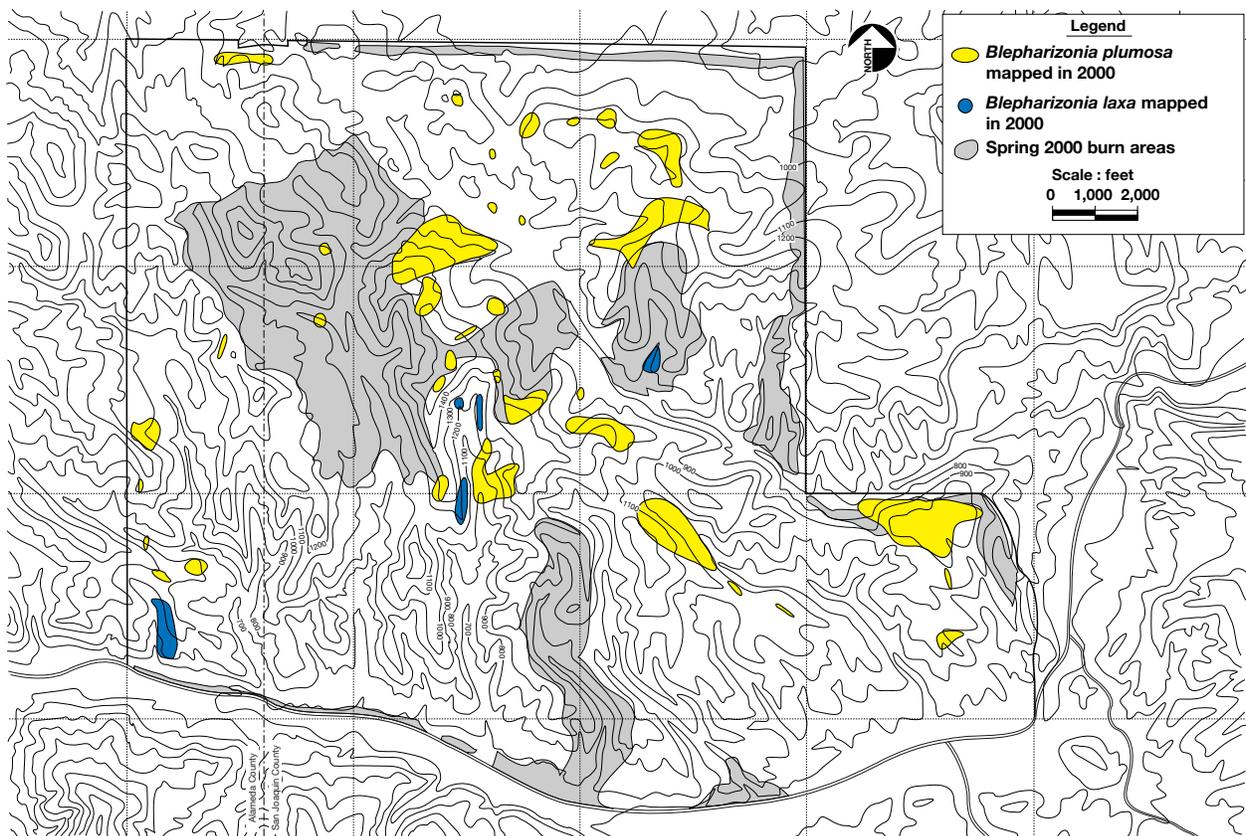
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Figure B15. Enlargement of Figure B11c. Areas burned in spring of 1998 shown.



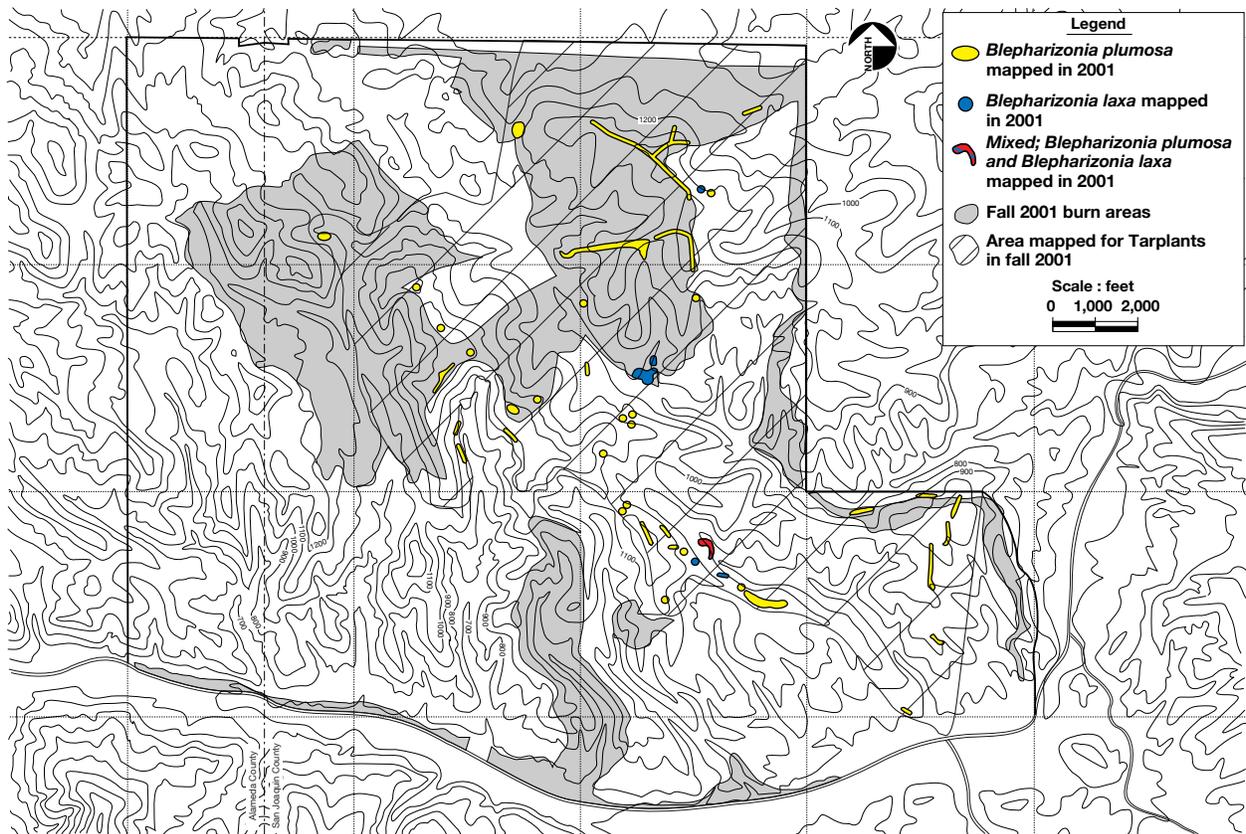
ERD-S3R-02-0248

Figure B16. Enlargement of Figure B12b. *Blepharizonia* populations mapped in the fall of 1999. Areas burned in spring of 1999 shown.



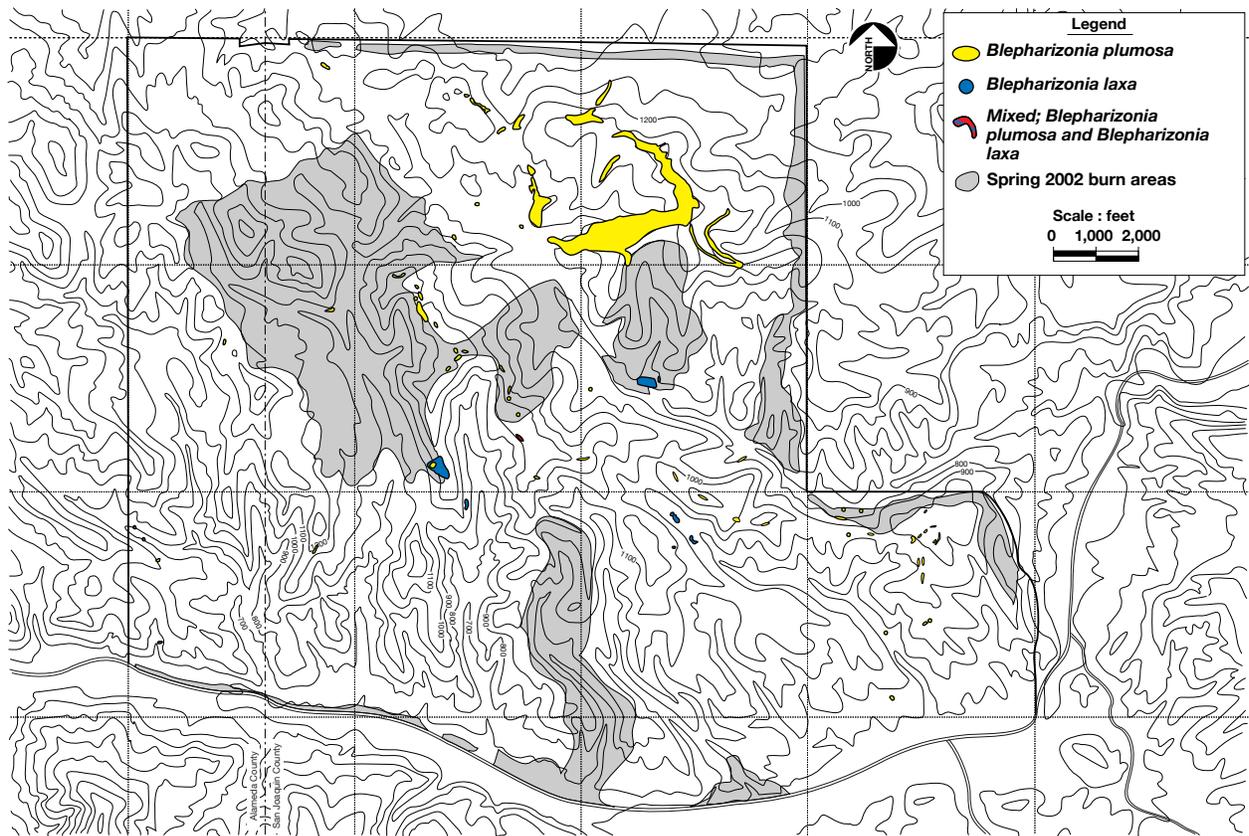
ERD-S3R-02-0249

Figure B17. Enlargement of Figure B12b. *Blepharizonia* populations mapped in the fall of 1997. Areas burned in summer of 2000 shown.



ERD-S3R-02-0250

Figure B18. Enlargement of Figure B12c. *Blepharizonia* populations mapped in the fall of 2001. Areas burned in spring of 2001 shown.



ERD-S3R-03-0128

Figure B19. Enlargement of Figure B12d. *Blepharizonia* mapped in the fall of 2002. Areas burned in spring of 2002 shown.

Section B
Tables

Table B1. Habitat characteristics of monitored *Blepharizonia plumosa* and *Blepharizonia laxa* populations at Site 300.

Population	Synecology	Elevation (ft)	Aspect	Slope (%)	Soil type	Management practices
Elk Ravine ^a (<i>B. plumosa</i>)	Exotic annual—native perennial mixed grassland, <i>Bromus hordeaceus</i> , <i>B. diandrus</i> , <i>Amsinckia intermedia</i> , <i>B. madritensis</i> ssp. <i>rubens</i> , <i>Poa secunda</i> , <i>Grindelia camporum</i> . Stands of <i>Leymus triticoides</i> along drainage route	≈700	north	50–75	Sandy to clay loam, Wisflat-Arburua-San Timoteo complex	Annually burned
Building 850 (<i>B. plumosa</i>)	Disturbed annual grass-land, <i>Nassella pulchra</i> and <i>Poa secunda</i> grasses on adjacent slope	≈1,300	north	30–50	rocky sandy to clay loam, Wisflat-Arburua-San Timoteo complex	Annually burned
Building 812 (<i>B. plumosa</i> and <i>B. laxa</i>)	Disturbed annual grassland, wetland herbaceous community in drainage, <i>Poa secunda</i> grasses on adjacent slopes	≈700	south	50–75	Sandy to clay loam, Wisflat-Arburua-San Timoteo complex	Annually burned
Middle Canyon (<i>B. laxa</i>)	Exotic annual grassland, <i>Avena</i> sp., <i>Bromus diandrus</i> , <i>B. rubens</i> , <i>B. hordeaceus</i> , <i>Hordeum marinum</i> , <i>Silybum marianum</i> , <i>Marah fabaceus</i> , <i>Gutierrezia californica</i> , <i>Phacelia distans</i>	≈1,300	east	50–75	Sandy to clay loam, Wisflat-Arburua-San Timoteo complex	Not burned

Adapted from Preston (1996).

^a Known as B834 Drainage in Preston (1996).

Table B2. Survivorship of *Blepharizonia plumosa* and *Blepharizonia laxa* marked prior to the burn at Building 850, Elk Ravine, Building 812, and Middle Canyon.

	Population	Species	<i>n</i> plants	Overall post-burn survivorship (%) ^a	<i>n</i> in burned area	Survivorship burned area (%) ^b	<i>n</i> in unburned area	Survivorship unburned area (%) ^c	<i>n</i> surveyed at flowering ^d	Survivorship post-burn to flowering (%)
1998	Building 850	<i>B. plumosa</i>	1681	25	ND	ND	ND	ND	414	13
	Elk Ravine		284	0	ND	ND	ND	ND	0	NA
1999	Building 850	<i>B. plumosa</i>	64	9	ND	ND	ND	ND	41	56
	Elk Ravine		169	3	ND	ND	ND	ND	4	0
2000	Building 850	<i>B. plumosa</i>	104	20	87	8	17	76	17	59
	Elk Ravine		170	1	168	0	2	50	9	44
2001	Building 850	<i>B. plumosa</i>	100	0	100	0	0	NA	20	0
	Elk Ravine		146	32	98	0	48	96	46	52
	Building 812	<i>B. laxa</i>	110	39	4	0	106	40	36	77
	Middle Canyon		19	75	0	NA	19	75	13	38
2002	Building 850	<i>B. plumosa</i>	97	3	97	3	0	NA	9	44
	Elk Ravine		100	0	100	0	0	NA	21	93
	Building 812	<i>B. laxa</i>	99	33	60	5	39	77	34	25
	Middle Canyon		65	31	0	NA	65	31	18	35

Notes:

n = Number of plants.

ND = No data.

NA = Not applicable (population unburned).

^a Number of surviving plants/*n*.

^b Number of surviving plants in burned area/*n* in burned area.

^c Number of surviving plants in unburned area/*n* in unburned area.

^d Additional plants were marked after burn in some years.

Table B3. Burn data for Building 850, Elk Ravine, and Building 812 *Blepharizonia* populations.

Building 850	1996	1997	1998	1999	2000	2001	2002
Date of burn	29 May	6 June	14 June	10 June	18 July	7 July	19 June
Temp (°F)	57	74	73	68	73	76	76
Wind (mph)	19	20	12	16	15	7	19
RH (%)	52.85	32.94	50.12	30.45	36.13	40.77	32.37
<hr/>							
Elk Ravine	1996	1997	1998	1999	2000	2001	2002
Date of burn	30 May	16 May	30 May	1 June	12 July	7 June	3 June
Temp (°F)	63	79	58	57	72	79	70
Wind (mph)	16	9	12	13	17	16	17
RH (%)	42.98	35.03	66.07	64.88	43.72	25.16	40.06
<hr/>							
Building 812	1996	1997	1998	1999	2000	2001	2002
Date of burn	NB	NB	NB	24 June	July	6 July	12 June
Temp (°F)	–	–	–	73	72	81	73
Wind (mph)	–	–	–	13	17	10	19
RH (%)	–	–	–	36.1	37.85	26.04	31.53

Notes:

– = Not applicable.

NB = Not burned.

Wind speed, temperature, and relative humidity are average values reported for each date except for Building 812 in 2000, in which averages for entire month are reported.

Table B4. Shannon's Index for *Blepharizonia* pre-burn nearest neighbors.

Population	Species	Burn status	H' 1999 (n)	H' 2000 (n)	H' 2001 (n)	H' 2002 (n)
Building 850	<i>B. plumosa</i>	Burned	1.64 (75)	1.81 (112)	1.99 (100)	1.79 (100)
Elk Ravine	<i>B. plumosa</i>	Burned	1.74 (175)	1.61 (175)	2.05 ^a (149)	1.87 (100)
Building 812	<i>B. laxa</i> / <i>B. plumosa</i>	Burned	–	–	1.99 ^a (125)	1.64 (100)
Middle Canyon	<i>B. laxa</i>	Not Burned	–	–	1.24 ^a (20)	1.67 (65)

Notes:

$H' = -\text{Sum (of } i = 1 \text{ to } S) (n_i/n) * \ln(n_i/n)$, where S is the number of species observed, n is the number of individuals observed, and n_i is the number of individuals in the i th species (Shannon and Weaver, 1949).

n = Number of plants.

B. plumosa = *Blepharizonia plumosa*.

B. laxa = *Blepharizonia laxa*.

– = Not determined.

^a Numbers revised from Carlsen et al., 2002.

Section C
***Eschscholzia rhombipetala* Monitoring**

Section C

Eschscholzia rhombipetala Monitoring

C-1. Introduction

Eschscholzia rhombipetala (the diamond-petaled poppy) is an extremely rare spring-flowering annual plant currently included on the California Native Plant Society (CNPS) List 1B (Tibor, 2001). This species was formerly included on the CNPS List 1A (Skinner and Pavlik, 1994), which includes plants that are presumed extinct. The historic range that includes the inner north Coast ranges, the eastern San Francisco Bay region, and the inner South Coast Ranges. The last herbarium collections of this plant were made in 1950 in San Luis Obispo county, and the species has since been presumed extinct. In 1993, a population of *E. rhombipetala* was discovered in the northern part of the Carrizo Plain by a plant taxonomist from California Polytechnic State University, San Luis Obispo (Keil, 2001). This population was observed again in 1995 but has not been seen since. At this location, they grow on heavy clay soils that accumulate water in the spring, forming vernal pools. The poppies grow in an ecotone on the higher areas between an *Amsinckia*-dominated mound and a *Layia*-dominated swale, in open patches. They grow as almost an understory to the taller *Lasthenia*, *Phacelia*, and various grasses (Clark, 2000).

Collections of *E. rhombipetala* have been made at Corral Hollow, both in 1937 (UC765993) and in 1949 (Espeland and Carlsen, 2003). A population of *E. rhombipetala* was identified during a habitat survey in 1997 at Site 300 (Preston, 2000). This original population (site 1) is located in the extreme southwest corner of the site (Figure C1). Like the Carrizo plain population, it occurs in an ecotone on heavy clay soils. The ecotone at Site 300 was formed by a landslide within a minor east-west drainage to a major north-south trending canyon. The landslide formed a slump at the bottom of the slide, with sharp scarp faces on the northern and southern sides of the slump. This *E. rhombipetala* population is found on the southern side of the slump (a north-west facing aspect) near the edge of the scarp, some distance into the surrounding grassland, and in the slump itself. The surrounding grasslands are composed primarily of the exotic grasses *Avena* and *Bromus*, with *Sonchus* and *Brassica* species being the primary forbs. The slump contains various grasses, along with *Blepharizonia plumosa* and *Blepharizonia laxa*.

A second population (site 2) of *E. rhombipetala* was discovered in spring of 2002 in another habitat survey, less than 3 km from the first population (Figure C1). This population occurs on a steep, northwest-facing slope on clay soil. While it may occur on an historic slump, the soil of the population area is not noticeably more active than its surroundings. The second population at site 2 occurs in a grassland of exotic species similar to that at site 1.

Eschscholzia rhombipetala is a small, erect annual, 5- to 30-cm tall. A member of the poppy family (Papaveraceae), it has typical poppy characteristics, but is quite diminutive and thus easily overlooked. The flower's yellow petals are 3- to 15-mm long from a barrel-shaped receptacle, and when in bud, may be erect or nodding, with a blunt or short point. The fruit is a capsule, generally

4- to 7-cm long, containing numerous round, net-ridged black seeds 1.3- to 1.8-mm wide (Clark, 1993).

Both Site 300 *E. rhombipetala* populations are located in remote portions of Site 300, outside of the programmatic areas. However, for conservation and management purposes, an understanding of the population dynamics of *E. rhombipetala* is desirable. Therefore, we are collecting census data on the *E. rhombipetala* populations, as well as characterization data on the surrounding plant community. These data will provide information concerning the mechanisms controlling the abundance and distribution of *E. rhombipetala*. During 2002, we completed an in-depth analysis of the data collected to date from the two Site 300 populations. The results of this analysis are reported here and are in press for publication in *Madroño*, the journal of the California Botanical Society (Espeland and Carlsen, 2003). The results of this analysis will inform continued monitoring and management activities of the Site 300 *E. rhombipetala* populations.

C-2. Methods and Materials

C-2.1. Census

The entire *E. rhombipetala* population was censused on 29 March 02 (site 1) and 05 Apr 02 (site 2). Height, flower number and capsule length were recorded for both sites. For site 1, the geographic features of the slump (SL), within 50 cm of the scarp next to the slump (SC), or in the surrounding grassland (GR), was recorded for all plants.

C-2.1.1. Data Analysis

Linear regression was performed using PROC GLM in SAS (SAS, 1990) to examine the relationship between plant height and number of floral units (buds + flowers + capsules) and capsule length. Tukey's separation of means was performed to determine the effect of geographic feature on the number of floral units (Steel et al., 1997).

C-2.2. Vegetation Sampling

Vegetation data were collected from 60 cm \times 60 cm plots on 29 Mar 2002 (site 1) and 5 Apr 2002 (site 2). For each plot, species were identified and their percent cover visually estimated. Percent bare ground and percent thatch cover was also recorded. At site 1, 31 plots containing *E. rhombipetala* were located throughout the *E. rhombipetala* population (both within the slump and scarp), and 32 plots that did not contain *E. rhombipetala* were randomly placed (including in the surrounding grassland). At site 2, 14 plots containing *E. rhombipetala* were located throughout the population, and 16 plots which did not contain *E. rhombipetala* were randomly placed (including into the surrounding grassland). Areas with differing dominant species were also mapped at both sites.

C-2.2.2. Data Analysis

Logistic regression using PROC LOGISTIC in SAS version 6.0 (SAS, 1990) was performed on vegetation data from all plots with complete data sets collected in 2001 and 2002 (144 plots total) from both sites to determine effects of vegetation on *E. rhombipetala* presence/absence.

C-2.3. Soil Sampling

Soil samples were collected from both sites on 08 May 02. Site 1 was divided into three sub-areas based on the geographic feature defined above (SL, SC, GR). Soil samples were collected from two locations in each sub-area, visually selected to be representative of the sub-area. Site 2 was not subdivided. Soil samples were collected from three locations, visually selected to be representative of site. At each sampling location, surface vegetation was scraped away with a trowel. The top 15 cm of soil in an approximately 30-cm² area was manually homogenized using the trowel. Soil samples were submitted to A&L Western Agricultural Laboratories in Modesto, California. Samples were analyzed for organic matter, nitrogen compounds (nitrate, ammonia, and total kjedhal nitrogen), sodium bicarbonate phosphorus, extractable cations, hydrogen, pH, cation exchange capacity, soluble salts, sulfate sulfur, zinc, manganese, iron, copper, boron and soil texture using standard agricultural methods as outlined in the North American Proficiency Testing Program and the USDA (Neufeld and Davison, 2000).

C-3. Results and Discussion

C-3.1. Census

The *E. rhombipetala* population at site 1 comprised 285 plants in 2002 (280 were marked and measured). The site 2 population contained 76 plants in 2002. Plants were small, with average heights ranging from 5.0±2.5 to 8.0±2.1 cm (Table C1). Plants as short as 2.5 cm were observed flowering and the largest plants recorded were approximately 14 cm tall. Most plants had only one flower open at a time, but senescent plants usually had several capsules per plant. The distribution of plants at site 1 was similar to that observed in 2001, although the northern and southern extent is somewhat contracted (Figure C2).

There was a significant positive relationship between plant height and number of floral units (buds + flowers + capsules) as well as between plant height and capsule length at site 1 (Table C2). Data were too few in 1999 to perform regression. In 1998, 2000 and 2001 slopes ranged from 0.09 to 0.19 and intercepts ranged from 0.26 to -0.17 ($p < 0.005$, $r^2 = 0.228$ to 0.325). In 2002 at site 1, more plants had floral units compared to other years and the average number of floral units per plant was greater than one for the first time; the slope of the regression was 0.10 and the intercept was 0.42 ($p < 0.0001$, $r^2 = 0.121$). Plant height was not a significant predictor of the number of floral units at site 2 ($p > 0.05$). Because the site 2 population was not discovered until 2002, there is no data for this population prior to 2002.

Plant height was even more closely tied to capsule length variation. Again, in 1998, 2000 and 2001, slopes were low (0.35 to 0.48), intercepts were small (-0.98 to -0.11) and r^2 was high (0.412 to 0.66, $p < 0.001$). In 2002, capsule lengths were longer than they had been in previous years. In 2002, height explained over 20% of capsule length variation at both site 1 and site 2, and this was a year where the regression intercept was high (1.08 and 1.19, respectively).

Geographic feature had an effect on plant performance. In 2002, plants had the most floral units at site 2 and in the slump at site 1 (Figure C3, $p < 0.05$). Plants in the slump generally performed well, either with the most floral units per plant (in 2000 and 2002), or with no significant difference between them and the best performers (which were plants in the grassland in 2001). The slump contained anywhere from 42% to 24% of the total plants in the site 1 population. Plants at

site 2, even though they were located in a grassland area without an active slump, performed as well as plants in the slump at site 1 in the year when both sites were monitored.

C-3.2. Vegetation Sampling

Figures C4 and C5 show the dominant vegetation types mapped visually in the *E. rhombipetala* population areas for 1999–2002. In 1999 and 2000, *Avena* sp. and *Bromus diandrus* were the dominant species in almost all of the areas at site 1. The slump itself had an extremely large bare ground component that was not repeated in succeeding years. The *E. rhombipetala* population was concentrated in one corner of the slump and adjacent grassland. The *E. rhombipetala* population expanded downslope in 2000 to double its population area. In 2001, the *E. rhombipetala* population expanded northward across the slope into the scarp. *Bromus* species were more mixed in 2001 and large areas of *Avena* sp. included a substantial forb component. *Poa secunda* became dominant in the scarp and the slump in 2001. In 2002, most of the vegetation patterns were similar to those in 2001, with the *E. rhombipetala* population expanding into the grassland areas upslope of the slump. *Lupinus microcarpus* became quite evident in the southern scarp and grassland in 2002. The small area of the site 2 population occurred in an *Avena/Bromus* matrix in 2002, downslope from a *Poa secunda* population (Figure C6). Pockets of *Bromus madritensis* subsp. *rubens*, *Lupinus microcarpus* and *Lupinus albifrons* occurred nearby. Table C3 shows plants that occurred in and around *E. rhombipetala* populations at both sites in all years where data were collected. Site 1 shows more species diversity than site 2.

Logistic regression showed that bare ground, thatch cover, exotic grass and exotic forb cover were important for predicting *E. rhombipetala* presence (Table C4). The logistic regression model was $p/(1-p) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 \dots + \beta_n x_n$, where p is the probability of *E. rhombipetala* presence in the plot, β_0 is the intercept, β_i is the parameter estimate, and x is the covariate. Bare ground, thatch, exotic grass, native grass, exotic forb, and native forb covers were used as covariates. All years where data were collected were used. Percent bare ground, percent thatch cover, percent exotic grass cover, and percent exotic forb cover all contributed significantly to the model ($p < 0.007$). Native grass and native forb cover did not contribute significantly to the prediction of *E. rhombipetala* presence. When the parameter estimate is negative, the covariate is negatively associated with *E. rhombipetala* presence. As thatch cover and exotic grass cover increase, the likelihood of *E. rhombipetala* presence decreases. Probability of *E. rhombipetala* presence increases as exotic forb cover and percent bare ground increase. Plots with *E. rhombipetala* averaged 45% bare ground cover compared to 20% bare ground in plots without *E. rhombipetala* (Table C5). Thatch cover was 39% in plots without *E. rhombipetala* and 14% in plots with *E. rhombipetala*. Exotic grass cover was 20% in plots with *E. rhombipetala* and 27% in plots without. Exotic forb cover averaged 6% in plots with *E. rhombipetala* and 3.5% in plots without *E. rhombipetala*.

C-3.3. Soil Sampling

Soils at sites 1 and 2 were clays and clay loams (Table C6). Soil nutrients were within the normal range of soils in the Altamont hills (data not shown, Webster-Scholten, 1994), but nitrogen and ammonia are relatively low (Table C6). In California coastal grasslands, heavily disturbed soils have been shown to be low in nitrogen (Stromberg and Griffin, 1996).

C-4. Discussion and Future Work

It is unclear whether these populations at Site 300 were present at the time the species was determined to be extinct. These populations occur away from regular Site 300 activities and may have been continuously present as aboveground plants. Alternatively, they may have been briefly extirpated and then rediscovered when the populations reappeared due to soil turnover or a long-range dispersal event. Long-distance dispersal events are rare and it is not easy to confirm the extinction of plants that have seed banks (Wolf, 2001). A long-term seed bank or even continuously present aboveground plants are more likely explanations of the existence of these populations than a recent dispersal event.

Our yearly census of *E. rhombipetala* at site 1 has shown a wide range in population size, from a low of 9 to a high of 285 individuals. Fluctuation in the size of small, annual plant populations is to be expected (Parson and Zedler, 1997; Pavlik and Espeland, 1998), but populations at both sites are still quite small. Although the nine plants observed at site 1 in 1999 may have produced enough seed to generate a population of 171 plants the following year, the 2002 appearance of plants upslope from where plants had been previously observed may indicate the presence of a seed bank for this population.

Reproductive success (number of floral units or capsule length) is better predicted from plant height in poor years than in good ones: the least predictive power came from regressions with very large intercepts, indicating that in a year like 2002 many of the smallest plants are able to put as much toward reproduction as the largest plants. Reproductive success was more strongly tied to plant height in years that were less favorable to *E. rhombipetala*. Small plants did less well relative to large plants in these poorer years with smaller population numbers. Although the year with the largest population size was also the year with the greatest small plant fitness, it is not clear at this time if these two factors are related.

The positive association of *E. rhombipetala* presence with bare ground, plus the better performance of plants in the active slump may indicate that some level of disturbance is necessary for plants of this species to do well. Plants were negatively associated with high levels of thatch and exotic grasses. Thatch indicates an area that has not been disturbed (Stromberg and Griffin, 1996), and an undisturbed environment is more likely to lead to the dominance of exotic grasses such as *Bromus diandrus* and *Avena* sp. (Brown and Bugg, 2001). The negative relationship between thatch and exotic grasses and *E. rhombipetala* may be due to either microhabitat preference or to an inability on the part of *E. rhombipetala* to compete with exotic annual grasses. Further observations of the population at site 2, where there is no obvious disturbance like the slump at site 1, may shed additional light on the nature of this possible relationship.

Populations of *E. rhombipetala* observed within the last decade have occurred on soils with a clay component. At the Carrizo Plain location, *E. rhombipetala* grows on heavy clay soils that accumulate water in the spring, forming vernal pools. The Carrizo Plain population is located in an ecotone on the higher areas between an *Amsinckia*-dominated mound and a *Layia*-dominated swale, in open patches. The plants are an understory to taller *Lasthenia*, *Phacelia*, and various grasses (Keil, 2001). Both population locations in the Altamont hills can be characterized as occurring on clay or clay loam soils. It is possible the species may occur in more locations than previously thought, as other surveys for this plant have focused on more gravelly soils (Clark, 2000). Clay soils can resist compaction through natural wetting and drying cycles (Ahmad, 1993), and this

attribute may be important for *E. rhombipetala* germination and growth. The low nitrogen levels in the soils may prevent overdominance of exotic annual grasses (Brown and Bugg, 2001), which may also encourage *E. rhombipetala* persistence.

Eschscholzia rhombipetala is a small-seeded plant, and as such, may be dependent on soil turnover to return banked seeds up to germinable depths. Small seeds buried too deeply in the soil are unable to germinate into seedlings (Zhan and Maun, 1994). It is likely that this species has a long-lived seed bank: studies of a small-seeded plant on serpentine clays showed that, for that species, seeds remained viable in the soil for more than eight years (Pavlik and Espeland, 1998). Germination and early growth is more important than later life history stages for many California native forbs (Brown and Bugg, 2001), and it is likely that the importance of these early life stages is even greater for those species with small seeds, which have fewer seed resources to overcome such hardships as limited light availability at early growth stages.

While we are currently unable to rigorously determine factors important to *E. rhombipetala* plant fitness, we have found some indication that there is a positive relationship between *E. rhombipetala* and factors related to disturbance. We have found that the strength of the relationship of plant size to reproductive output changes among years and that in some years many small plants can have fairly high fitness. Continuing yearly population censuses and the collection of vegetation characterization data will help us to determine factors that influence greater plant fitness and higher population sizes at the two sites at Site 300.

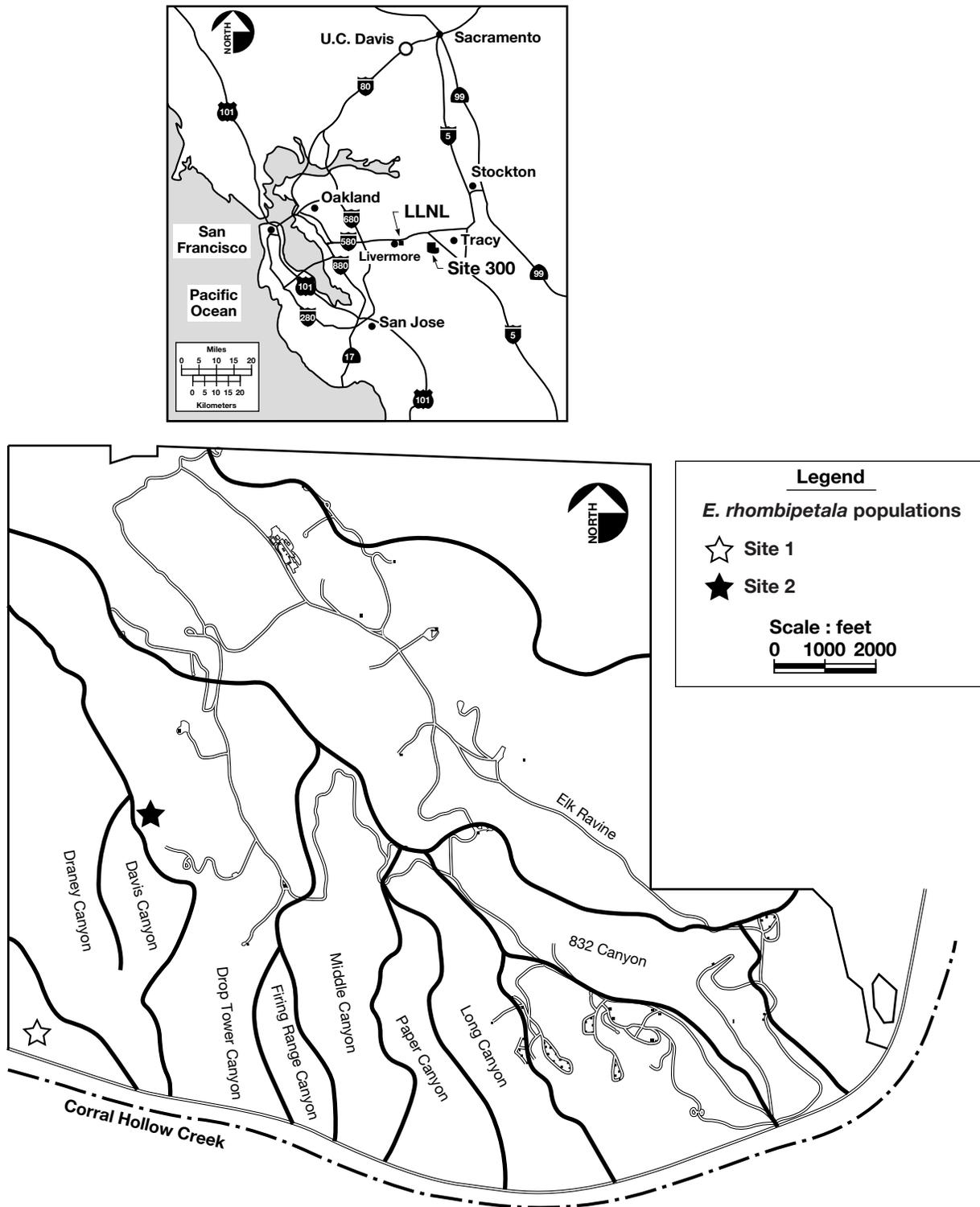
We will continue to interact with Dr. Curtis Clark of the California State Polytechnic University as he works to determine chromosome number and additional genetic characteristics of *E. rhombipetala*. We will maintain contact with Dr. Dave Keil of the California Polytechnic State University in San Luis Obispo and arrange for a visit to the Carrizo plains population when it re-occurs. These exchanges of information will enhance our ability to manage the Site 300 *E. rhombipetala* populations.

C-5. References

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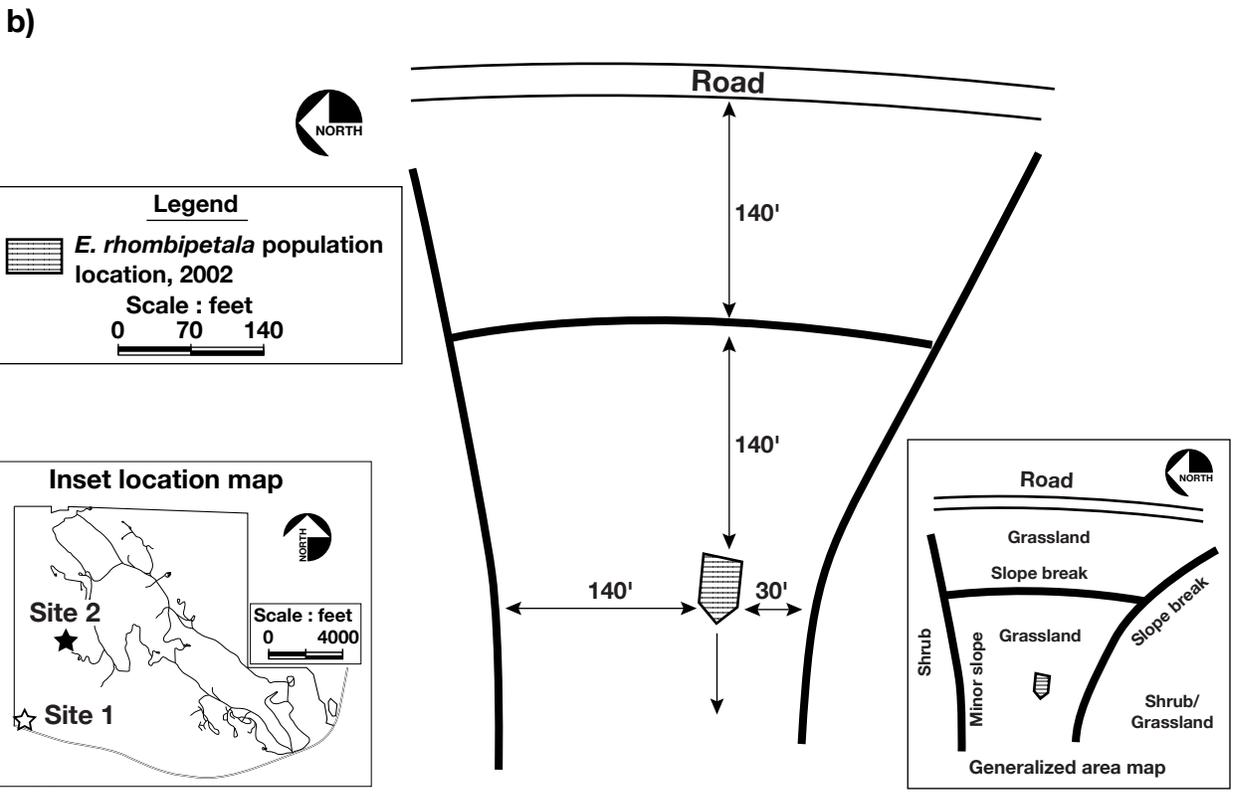
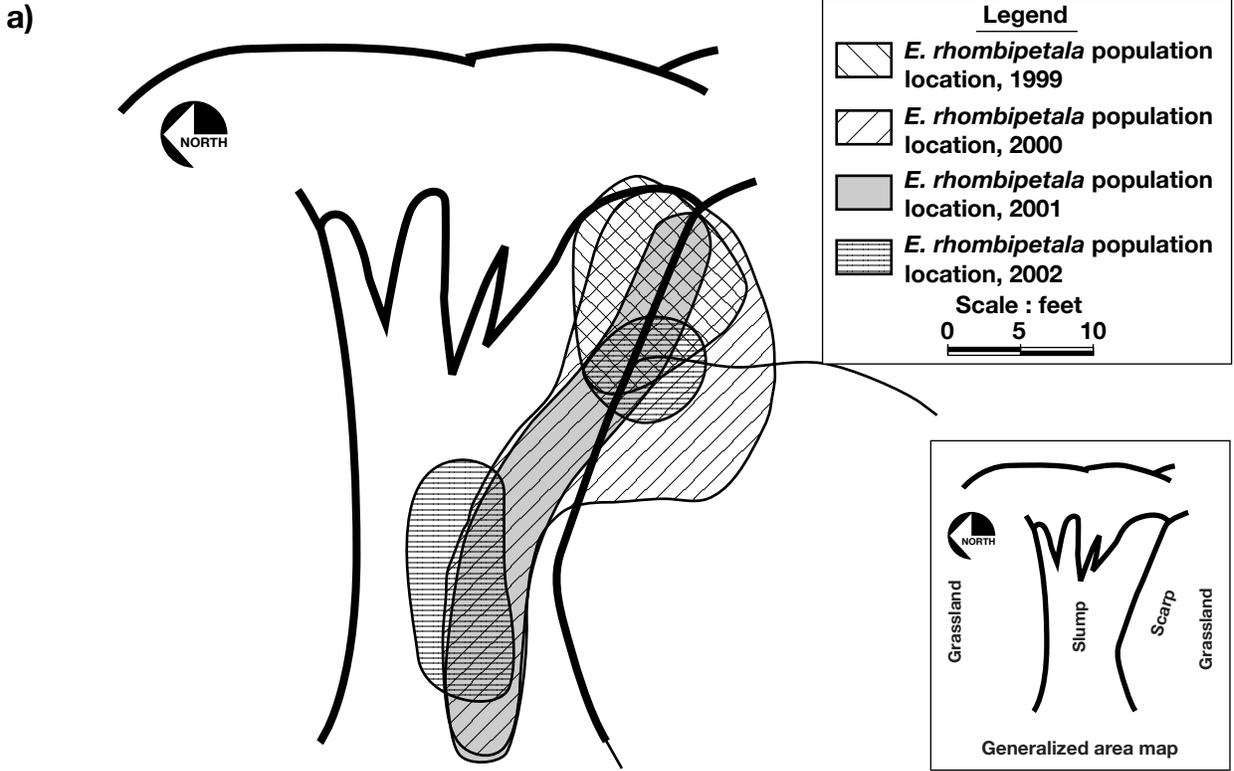
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Section C
Figures



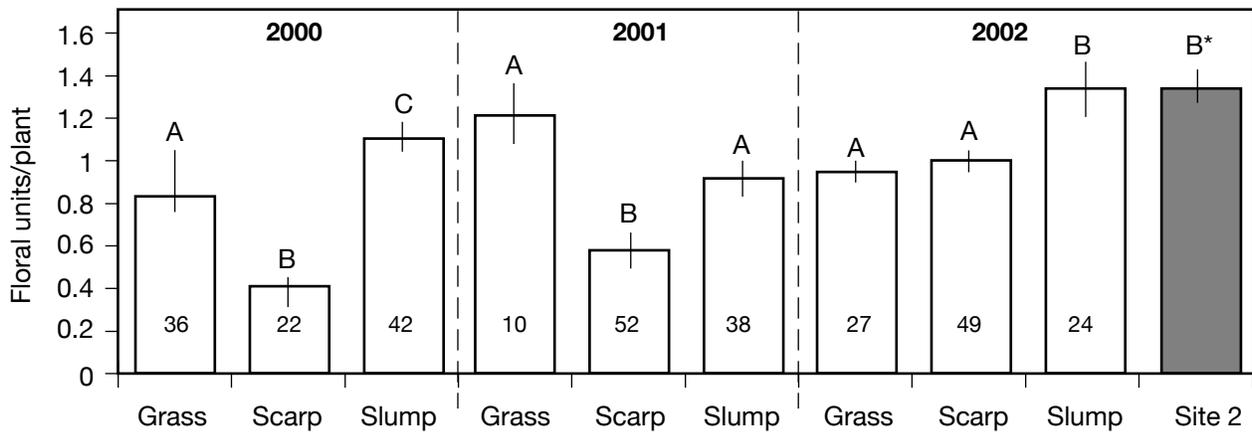
ERD-S3R-03-0127

Figure C1. Locations of *Eschscholzia rhombipetala* populations Lawrence Livermore National Laboratory (LLNL) Site 300.



ERD-S3R-03-0130

Figure C2. *Eschscholzia rhombipetala* population location 1999–2002: a) site 1, b) site 2.



ERD-S3R-03-0040

Figure C3. Number of floral units per plant by location at site 1 in 2000–2002 and at site 2 in 2002. All bars are one standard error. Different letters indicate significant differences ($p < 0.05$) among locations within years. Numbers inside bars indicate the percent of plants found at each location in site 1. *Site 2 also different from site 1 when all site 1 locations are lumped.

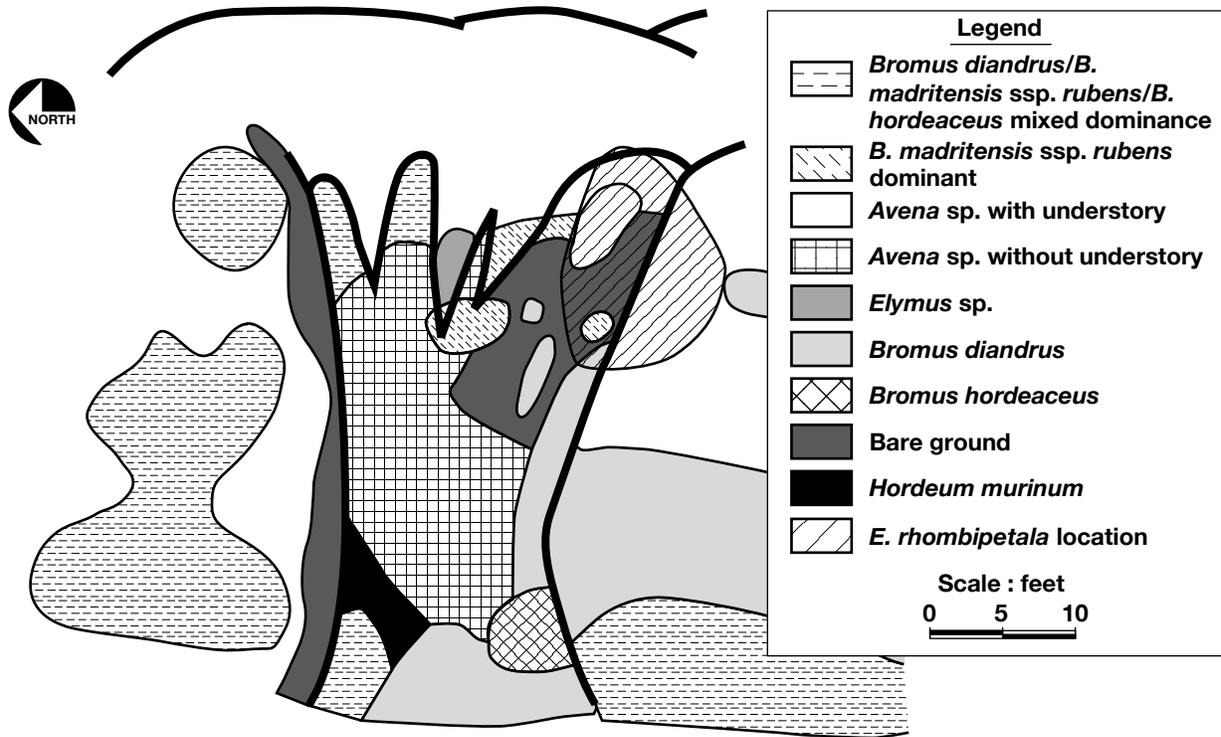
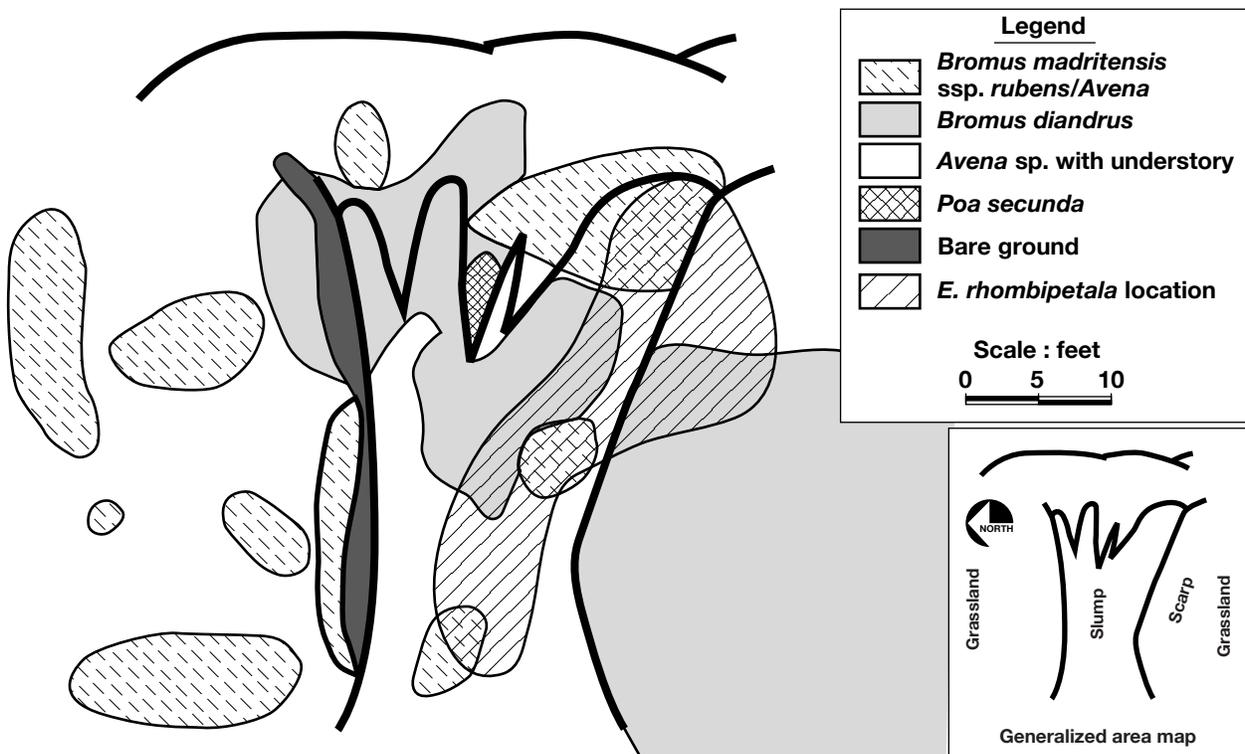
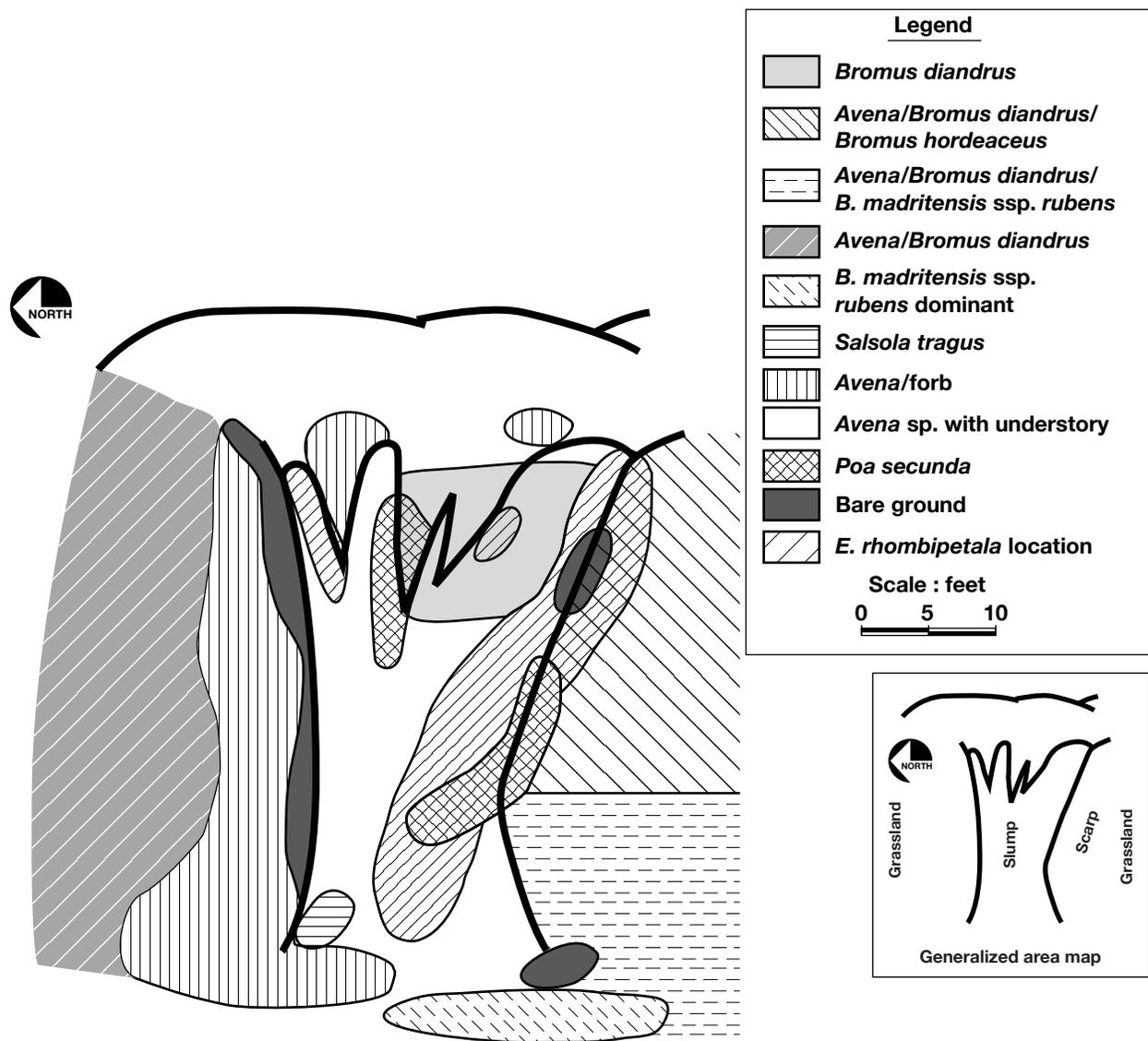


Figure C4. Dominant vegetation type and *Eschscholzia rhombipetala* location, site 1: 1999.



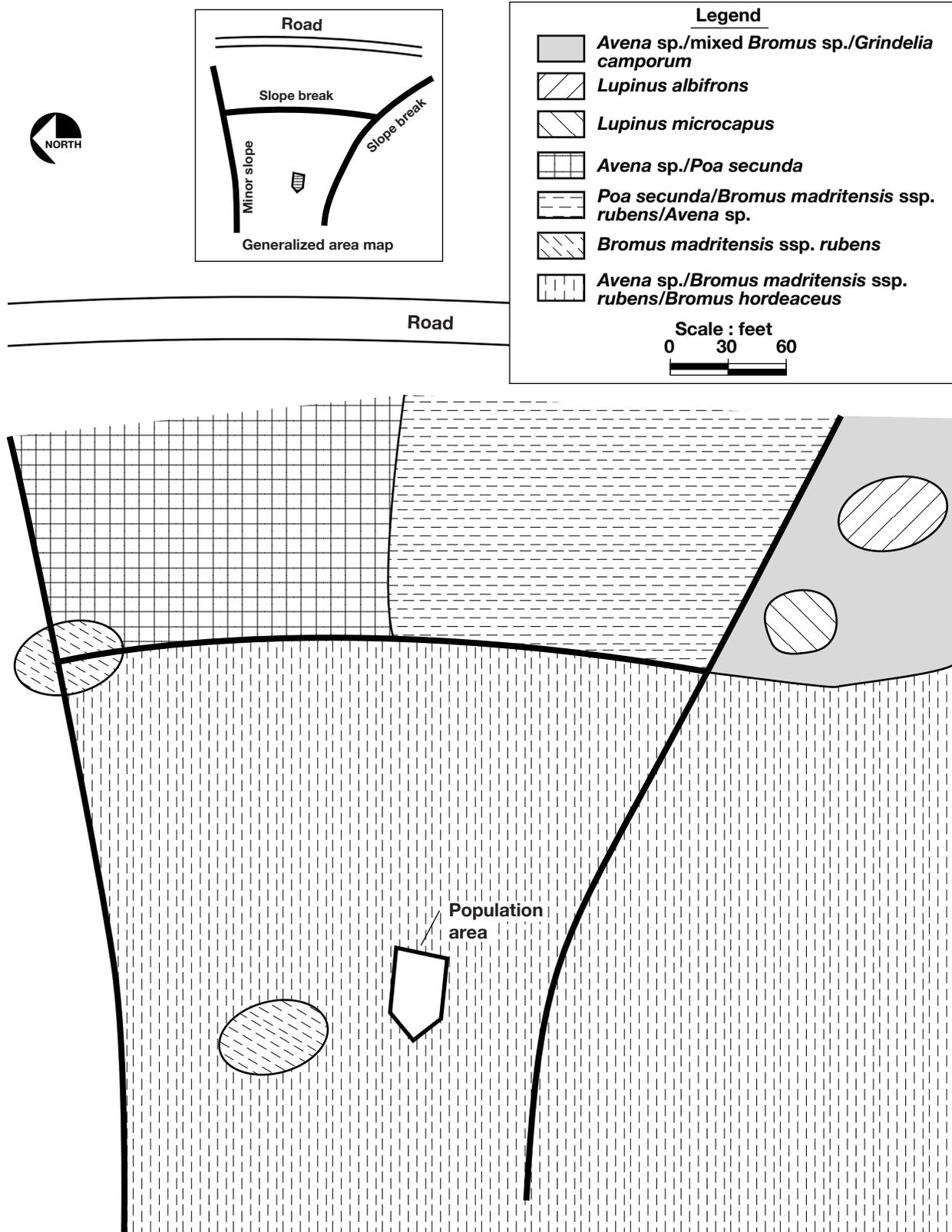
ERD-S3R-03-0026

Figure C5. Dominant vegetation type and *Eschscholzia rhombipetala* location, site 1: 2000.



ERD-S3R-03-0027

Figure C6. Dominant vegetation type and *Eschscholzia rhombipetala* location, site 1: 2001.



ERD-S3R-03-0131

Figure C7. Dominant vegetation type and *Eschscholzia rhombipetala* location, site 2: 2002.

Section C
Tables

Table C1. Height, number of floral units (buds + flowers + capsules) per plant, and capsule length for marked *Eschscholzia rhombipetala* plants: 1998–2002. All averages are \pm one standard deviation.

Site	Date measured	Height (cm)	No. of floral units/plant	n^a	Capsule length (cm)	n^b
1	18 Apr 98	7.5 \pm 2.8	0.4 \pm 0.5	24	2.8 \pm 1.4	16
1	30 Apr 99	6.0 \pm 1.8	0.7 \pm 0.7	9	2.1 \pm 0.6	6
1	24 Mar 00	5.5 \pm 2.1	0.6 \pm 0.5	171	2.3 \pm 1.4	44
1	30 Mar 01	5.0 \pm 2.5	0.3 \pm 0.5	189	2.8 \pm 1.8	72
1	29 Mar 02	6.8 \pm 2.5	1.1 \pm 0.7	280	3.4 \pm 1.6	73
2	05 Apr 02	8.0 \pm 2.1	1.4 \pm 0.7	76	3.3 \pm 0.3	63

^a Number of plants measured is the same for the height and number of flowers measurement. Plants with no flowers were included in the average.

^b Number of plants measured for capsule length includes only those plants with capsules.

Table C2. Linear regression ($y = ax + b$) of number of floral units (buds + flowers + capsules) and capsule length to plant height (x): 1998, 2000, 2001, and 2002. 1999 data too few for regression.

Year	Slope (a) (error)	Intercept (b) (error)	Pr > t	R-square
<i>Number of floral units (y)^a</i>				
1998	0.09 (0.03)	0.26 (0.22)	0.0034	0.316
2000	0.14 (0.02)	0.09 (0.12)	<0.0001	0.228
2001	0.19 (0.02)	-0.17 (0.11)	<0.0001	0.325
2002 (site 1)	0.10 (0.02)	0.42 (0.12)	<0.0001	0.121
2002 (site 2)		>0.05		
<i>Capsule length (y)^b</i>				
1998	0.35 (0.06)	-0.62 (0.52)	<0.0001	0.660
2000	0.48 (0.09)	-0.98 (0.63)	<0.0001	0.412
2001	0.42 (0.06)	-0.11 (0.42)	<0.0001	0.436
2002 (site 1)	0.25 (0.04)	1.08 (0.34)	<0.0001	0.235
2002 (site 2)	0.45 (0.06)	1.19 (0.49)	<0.0001	0.222

^a Plants with no flowers were included in this analysis.

^b Only plants with capsules were included in this analysis.

Table C3. Plant species found in and around *Eschscholzia rhombipetala* populations: 1999–2002.

<u>Native</u>	<u>Exotic</u>
Grasses	
<i>Elymus</i> sp.	<i>Avena</i> sp.
<i>Poa secunda</i>	<i>Bromus diandrus</i>
	<i>Bromus hordeaceus</i>
	<i>Bromus madritensis</i> subsp. <i>rubens</i>
	<i>Hordeum murinum</i>
	<i>Vulpia myuros</i>
Forbs	
<i>Amsinckia intermedia</i>	<i>Brassica</i> sp.
<i>Amsinckia mensezii</i>	<i>Carduus pynoccephalus</i>
<i>Blepharizonia laxa</i>	<i>Centaurea melitensis</i>
<i>Blepharizonia plumosa</i>	<i>Erodium cicutarium</i>
<i>Brodiaea</i> sp.	<i>Medicago polymorpha</i>
<i>Claytonia parviflora</i>	<i>Salsola tragus</i>
<i>Dichelostema capitatum</i>	<i>Sanicula bipinnata</i>
<i>Eschscholzia rhombipetala</i>	<i>Sonchus</i> sp.
<i>Galium aparine</i>	
<i>Grindelia camporum</i> *	
<i>Gutierrezia californica</i>	
<i>Lepidium nitidum</i>	
<i>Lotus wrangellianus</i>	
<i>Lupinus albifrons</i> *	
<i>Lupinus microcarpus</i>	
<i>Monolopia major</i>	
<i>Stylomecon heterophylla</i>	
<i>Trifolium</i> sp.	

Notes:

Bold face indicates species found at both site 1 and site 2. * indicates species found only at site 2. All other species found only at site 1.

For plants identified only to genus, native versus exotic identifications were made using species lists generated by Taylor and Davilla (1986).

Table C4. Results of the logistic regression: the effect of vegetation on *Eschscholzia rhombipetala* absence, sites 1 and 2, 1999–2002.^a

Covariate x	p-value	β^a	Odds ratio ^b	Confidence interval	Maximum measured x value ^a
Intercept $\beta = -0.67$	0.411				
% bare ground	<0.001	0.046	1.047	1.021–1.074	80
% thatch cover	<0.001	-0.053	0.948	0.919–0.978	80
% exotic grass cover	<0.001	-0.058	0.944	0.906–0.984	70
% native grass cover	0.912	-0.004	0.996	0.919–1.078	40
% exotic forb cover	0.007	0.151	1.163	1.043–1.297	20
% native forb cover	0.990	-0.001	0.999	0.838–1.190	12.5

^a Model fit $p < 0.001$, $n=149$ (69 plots with no *E. rhombipetala*, 75 plots with *E. rhombipetala*). The model is $p/(1-p) = \beta + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n$ where p is the probability of *E. rhombipetala* absence from the plot, β is the intercept, β_i is the parameter estimate, and x is the covariate. In the model, bare ground, thatch, exotic grass, native grass, exotic forb, and native forb covers were used as covariates.

^b Odds ratio is probability *E. rhombipetala* present : probability *E. rhombipetala* absent.

Table C5. Vegetation characteristics of plots with and without *Eschscholzia rhombipetala*, sites 1 and 2: 1999–2002. All values are averages \pm one standard deviation.

Plot type	% bare ground	% thatch cover	% exotic grass cover	% native grass cover	% exotic forb cover	% native forb cover	<i>n</i>
no <i>E. rhombipetala</i>	19.6 \pm 15.5	38.7 \pm 25.2	27.0 \pm 11.8	2.1 \pm 6.1	3.5 \pm 4.3	2.2 \pm 3.0	74
with <i>E. rhombipetala</i>	44.9 \pm 27.0	13.9 \pm 14.0	20.3 \pm 11.4	2.8 \pm 6.0	6.1 \pm 5.0	2.8 \pm 3.4	75

Note:

n = Number of plants.

Table C6. Characteristics of soil collections and their locations.

Location	Slope	Aspect	% sand	% silt	% clay	Soil type	NO ₃ -N ^a	NH ₄ -N ^b
Site 1								
Slump	32°	W	20.0 (1.4)	36.0 (4.2)	44.0 (2.8)	clay	6.5 (0.7)	<2.5
Scarp	42°	N	31.0 (5.7)	31.0 (0.0)	38.0 (5.7)	clay loam	6.5 (0.7)	3.1 (0.8)
Grassland	31°	NW	37.5 (14.8)	30.0 (1.4)	35.0 (12.7)	clay loam	6.0 (0.0)	<2.5
Site 2								
	32°	NW	33.7 (2.3)	23.0 (0.0)	43.3 (2.3)	clay	5.3 (0.6)	2.5 (0.0)

^a Nitrate nitrogen (ppm).

^b Ammonia nitrogen

Section D
New Discoveries

Section D

New Discoveries

D-1. Introduction

A botanical inventory of Site 300 was completed in 2002 (Preston, 2002). Field surveys were conducted in late April and May of 1997, March and April in 2002, and September of 2002. These field surveys consisted of walking meandering transects that traversed the entire site. All species encountered during these transects were recorded and the location of special status species were mapped. In addition, at each special status species occurrence, the number of individuals observed, a habitat description, and associated species were recorded.

Prior to the 2002 surveys, four rare plant species, *Amsinckia grandiflora*, *Eschscholzia rhombipetala*, *Blepharizonia plumosa*, and *Delphinium gypsophilum* subsp. *gypsophilum*, were known to occur at Site 300. As a result of the 2002 field surveys, four special status plant species were added to this list. These species were not previously known to occur at Site 300, previously known from Site 300 but not considered rare until recently, or previously misidentified. All eight species and their federal, state and CNPS status are shown in Table D1. Three of the rare species identified in 2002, California rock jasmine (*Androsace elongata* subsp. *acuta* (Greene) Robbins), stinkbells (*Fritillaria agrestis* Greene), and hogwallow starfish (*Hesperis matronalis* [Benth.] Gray), are included on the California Native Plant Society's List 4 (Tibor, 2001). List 4 includes species of limited distribution that are not considered rare from a statewide perspective, but are uncommon enough that their status should be monitored regularly. The third species, round-leaved filaree, *Erodium macrophyllum* H. & A., is a California Native Plant Society List 2 species (Tibor, 2001). List 2 includes plants that are rare, threatened, or endangered in California, but more common elsewhere. The California Native Plant Society is currently considering upgrading *Erodium macrophyllum* from List 2 to List 1B (Tibor, 2003).

D-1.1. *Androsace elongata* subsp. *acuta*

Androsace elongata subsp. *acuta* is a small annual herb in the Primulaceae (primrose family) that is typically only 3 to 12 cm tall (Cholewa and Henderson, 1993). This species has a basal rosette of leaves, and its small flowers have a reddish calyx and white corolla. Flowers occur in umbels subtended by small bracts and located on small leafless stalks.

Androsace elongata subsp. *acuta* was found in 37 locations at Site 300 during the 2002 botanical inventory (Preston, 2002). This species was previously observed at Site 300 during the 1986 botanical surveys (Biosystems, 1986), although at that time its distribution was not well known, and it was not considered rare (Preston, 2002). At Site 300, *A. elongata* subsp. *acuta* is found on moss and lichen-covered banks and rock outcrops on north-facing slopes at elevations between 300 and 375 meters. Associated species in these areas include *Poa secunda*, *Trifolium willdenovii*, *Erodium cicutarium* and other annual grasses and forbs (Preston, 2002).

The CNPS R-E-D (rarity-endangerment-distribution) code for *A. elongata* subsp. *acuta* is 1-2-2. A rarity code of 1 describes species that are rare, but found in sufficient numbers and distributed widely enough that the potential for extinction is low at this time. The endangerment and distribution codes of 2 are given to species that are endangered in a portion of its range (endangerment) and rare outside of California (distribution).

The range of *A. elongata* subsp. *acuta* extends from Oregon to Baja California, although it is most commonly found in the coastal hills from the San Francisco Bay area into southern California and the San Joaquin Valley at elevations less than 1200 meters (Cholewa and Henderson, 1993). Jepson Herbarium specimens of *A. elongata* subsp. *acuta* were frequently collected from north facing slopes in grassy habitat (Baldwin et al., 2002). Specimens also frequently note rock soils or adjacent rock outcrops.

D-1.2. *Erodium macrophyllum*

Of the six species of *Erodium* that occur in California, *Erodium macrophyllum* is one of two native species (Taylor, 1993). The remaining four species are native to Mediterranean Europe or Australia (Taylor, 1993). The range of *E. macrophyllum* is reported in the California Native Plant Society's Inventory of Rare and Endangered Plants and the Jepson Manual extends from northern California to northern Mexico and southern Utah to the east (Tibor, 2001; Taylor, 1993). Gillespie (2003) argues that reports of *E. macrophyllum* in southern Utah are based on a mislabeled specimen, and that this species only occurs outside of California in southern Oregon and northern Baja. In California, *E. macrophyllum* occurs in the Great Valley, San Francisco Bay area, central and south coasts, and the Channel Islands (Taylor, 1993). The CNPS R-E-D code for this population is 2-3-1 indicating that this species has a limited number of occurrences, is endangered in California, and more widespread outside of California (Tibor, 2001).

Prior to 2002, when one population of 200 plants was observed at Site 300, this species was previously not known to occur at Site 300 (Preston, 2002). The Site 300 population occurs in fire trails and on adjacent berms that are annually graded. This population occurs in the northwestern quarter of Site 300 in areas vegetated by annual grassland communities. In this area, *Erodium macrophyllum* was found in association with *Avena barbata*, *Erodium cicutarium*, *Monolopia major*, *Phaelia ciliata*, *Lepidium nitidum*, *Amsinckia lycopoides*, *Trifolium willdenovii*, *Triteleia laxa*, and *Achyrachaena mollis* (Preston, 2002).

Morphological data suggest that *E. macrophyllum* should be segregated into a new monotypic genus *California* (Aldasoro et al., 2002). Aldasoro et al. (2002) describes three characteristics that separate *E. macrophyllum* from other species of *Erodium* (and the genus *Monsonia*): arrangement of stamens, mericarp bristle morphology, and leaf shape. All species in the genus *Erodium* have five fertile stamens and five staminodes. Unlike other *Erodium* species, *E. macrophyllum* has five stamens with two lateral wing-like expansions on the filaments and no staminodes. Other *Erodium* species have a semicircular rim surrounding each bristle on the fruits. *Erodium macrophyllum* fruit bristles lack this rim. Finally, unlike other *Erodium* species, the leaves of *E. macrophyllum* are rounded with a cordate base and subpalmate veins. Other species of *Erodium* have subpinnate or pinnate veins.

D-1.3. *Fritillaria agrestis*

During the 2002 Site 300 botanical surveys, *Fritillaria agrestis* was found in five locations in the northwest corner of Site 300 (Preston, 2002). One of these five locations contained several hundred plants while the remaining four areas had less than 100 plants. *Fritillaria agrestis* was also found during 1986 rare plant surveys conducted at Site 300 (BioSystems, 1986), but it was misidentified as *Fritillaria biflora* (Preston, 2002).

This species occurs in scattered locations throughout the Sierra Nevada foothills from Placer County to Kern County, and the Great Valley and the Coast Ranges from Mendocino County to Ventura County (Ness, 1993; Tibor, 2001). In these areas, it is reported to occur in a variety of different habitat types including chaparral, cismontane woodland, and lower montane coniferous forests (Tibor, 2001) in clay depressions and other heavy soils (Ness, 1993). At Site 300, *F. agrestis* is found in native grasslands in association with *Poa secunda*, *Nassella pulchra*, *Allium serra*, *Dichelostemma capitata*, *Chlorogalum pomeridianum*, *Viola pedunculata*, and *Sanicula bipinnata*.

Fritillaria agrestis has a CNPS R-E-D code of 1-2-3. The rarity code of 1 indicates that although this species is rare, it is found in sufficient numbers and its distribution is wide enough that its potential for extinction is low at this time. This species is endemic to California (distribution code 3), and it is endangered in a portion of its range (endangerment code 2)

Fritillaria agrestis grows from a bulb and has nodding bell-shaped flowers as is common for this genus. *Fritillaria agrestis* is distinguished from similar species by its unpleasant odor and perianth that is greenish white or yellow (Ness, 1993).

D-1.4. *Hesperevax caulescens*

This species was observed in one location at Site 300 during the 2002 botanical surveys in native grasslands (Preston, 2002). This population is located on an east-facing slope in an area with friable clay soils. Common species in this area included *Poa secunda*, *Amsinckia eastwoodiae*, *Achyranchaena mollis*, *Lasthenia minor*, and *Phlox gracilis*. *Hesperevax caulescens* was also previously identified at Site 300 during the rare plant surveys conducted in 1986 (BioSystems, 1986) although this species was not known to be rare at that time. *Hesperevax caulescens* occurs in the Coast Range, Sierra Nevada foothills and the Great Valley from Tehama County in the north to Kern and San Luis Obispo Counties in the south; *H. caulescens* is also reported to occur in San Diego County (Morefield, 1993; Tibor, 2001). Throughout its range, *H. caulescens* occurs in grasslands in the dried bottoms of vernal pools and other mesic clay soils (Morefield, 1993; Tibor, 2001).

Hesperevax caulescens has a CNPS R-E-D code of 1-2-3. The rarity code of 1 indicates that although this species is rare, it is found in sufficient numbers and its distribution is wide enough that its potential for extinction is low at this time. This species is endemic to California (distribution code 3), and it is endangered in a portion of its range (endangerment code 2)

Hesperevax caulescens is a small annual that is typically less than 18-cm tall and has woolly hairs on its leaves and stems that give it a gray-green color. This species has leaves clustered near the stem tips and disciform heads of small flowers (Morefield, 1993). These small flowers occur in clusters of 10 to 40 flowers subtended by many leaves. From the turn of the century until 1992, this species was commonly included in the genus *Evax*. In 1992, Morefield proposed segregated

H. caulescens and two other species into the genus *Hesperevax* because of morphological and biogeographical evidence (Morefield, 1992).

D-2. Discussion

Of the four new additions to the list of rare plants at Site 300, three (*Fritillaria agrestis*, *Hesperevax caulescens*, and *Androcace elongata* subsp. *acuta*) are included on CNPS List 4. These species are not considered threatened or endangered on a statewide basis, but they are uncommon enough to warrant monitoring (Tibor, 2001). The fourth species, *Erodium macrophyllum*, is less common. It is rare, threatened, or endangered within California and more common elsewhere, CNPS List 2 (Tibor, 2001). *Erodium macrophyllum* is rare enough to warrant protection under the California Endangered Species Act and must be considered during preparation of CEQA documents. Rare plant research and monitoring at Site 300 focuses on species with the greatest rarity and regulatory protection. Because of this, *Erodium macrophyllum* will be included in the Site 300 rare plant monitoring and research program in 2003. In 2003, the distribution of *Erodium macrophyllum* at Site 300 will be mapped, and a study of the survivorship of this species and *Erodium cicutarium* will be conducted. The results of these studies will be presented in the 2002/2003 Site 300 rare plant monitoring and research annual report. Populations of List 4 species will be occasionally monitored to determine their status at Site 300.

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Table D1. Names and status of rare plant species that occur at Site 300.

Scientific and common name	Status Federal/State/CNPS	CNPS R-E-D Code
<i>Amsinckia grandiflora</i> large-flowered fiddleneck	FE/CE/1B	3-3-3
<i>Androsace elongata</i> ssp. <i>acuta</i> California androsace	-/-/4	1-2-2
<i>Blepharizonia plumosa</i> big tarplant	-/-/1B	3-3-3
<i>Delphinium gypsophilum</i> ssp. <i>gypsophilum</i> gypsum-loving larkspur	-/-/4	1-2-3
<i>Erodium macrophyllum</i> round-leaved filaree	-/-/2	2-3-1
<i>Eschscholzia rhombipetala</i> diamond-petaled California poppy	-/-/1B	3-3-3
<i>Fritilaria agrestis</i> stinkbells	-/-/4	1-2-3
<i>Hesperevax caulescens</i> hogwallow starfish	-/-/4	1-2-3

Status:

FE = Endangered under the Federal Endangered Species Act.

CE = Endangered under the California Endangered Species Act.

CNPS List 1A = Plants presumed extinct in California.

CNPS List 1B = Plants rare, threatened, or endangered in California and elsewhere.

CNPS List 2 = Plants rare, threatened, or endangered in California, but more common elsewhere.

CNPS List 3 = Plants about which we need more information – a review list.

CNPS List 4 = Plants of limited distribution – A watch list.

CNPS R-E-D Code:

R – Rarity

1. Rare, but found in sufficient numbers and distributed widely enough that the potential for extinction is low at this time.
2. Distributed in a limited number of occurrences, occasionally more if each occurrence is small.
3. Distributed in one to several highly restricted occurrences, or present in such small numbers that it is seldom reported.

E – Endangerment

1. Not endangered.
2. Endangered in a portion of its range.
3. Endangered throughout its range.

D – Distribution

1. More or less widespread outside California.
2. Rare outside California.
3. Endemic to California.